THE JOURNAL OF ENGINEERING EDUCATION

ublished by THE SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION

EW SERIES
L. XXVI., NO. 8 APRIL, 1936 Subscription Price $3.00 per year
Single copies 50 cents

Published April 2nd!

ARCHITECTURAL GRAPHIC STANDARDS

Second Revised Edition

By CHARLES G. RAMSEY and HAROLD R. SLEEPER
Associate Architects with Frederick W. Ackerman, Architect, New York City

cording to our records there is scarcely a department of architecture in the colleges of this country that not using "Ramsey and Sleeper" in some form in its classes. In the years since the publication of this ok we have received only the highest approval of its value and usefulness. Of tremendous importance, erefore, is the announcement that there is now available a revised and modernized second edition of this nous book.

e new edition is approximately 22% larger than the previous one. It contains 260 plates, 57 of which entirely new, 47 dealing with subjects not hitherto treated, and the remaining 10 covering old subjects ought up to date and amplified. All plates that have been retained from the old edition have been efully revised to coincide with the latest standards and good practice.

4 pages 9¼ by 11½ $6.00

•

Ready Spring 1936

IRCRAFT ENGINES — Theory, Analysis, Design and Operation

By ARTHUR B. DOMONOSKE, *Professor of Mechanical Engineering*, and VOLNEY C. FINCH, *Associate Professor of Mechanical Engineering; both at Stanford University.*

new textbook for use in engineering courses for undergraduate and postgraduate students, covering basic ory and principles of aircraft-engine design and operation.

•

John Wiley & Sons, Inc., 440 Fourth Avenue, New York

4th Annual Meeting, S.P.E.E., University of Wisconsin
Madison, Wis., June 23-26, 1936

THE NATION'S *Calling* LIST

THE telephone directory is the nation's calling list. Millions of people refer to it daily — in homes and offices and in public pay stations. It is the busiest book — it plays a part in countless activities.

For the names in the telephone book are more than names. They are friendships and homes and families. They are bridge parties and golf games—business successes — buyers and sellers of wheat or pins or skyscrapers.

More than 12,000,000 names are listed in the directories of the operating companies of the Bell System. You can go straight to any one of these millions of people — easily, quickly and economically — by telephone.

The classified directory is an important feature of your telephone book. It is a handy, reliable buying guide—a quick, easy way to find "Where To Buy It."

BELL TELEPHONE SYSTEM

READY IN MAY

COMPLETE, THOROUGH-GOING, MODERN IN EVERY DETAIL

TECHNICAL DRAWING

By

F. E. Giesecke, A. Mitchell, *and* H. C. Spencer,

of the Agricultural and Mechanical College of Texas

This whole text is so clear and complete that it should relieve the instructor of much additional explanation in the classroom, and it is thoroughly up to date. Particularly full material is given on fundamentals such as geometrical construction, projection, pictorial representation, dimensioning, and working drawings. The arrangement of material and pedagogical theory are consistent with the changing trend in the teaching of drafting. The standard practices recently adopted by the Standards Committee of the A.S.M.E. are followed. All illustrative material is exceptionally good. A very complete and well-organized series of problems accompanies each chapter. To be published in May. $3.00 (probable).

***Technical Drawing Problems** by the same authors, a workbook to accompany the text, will be ready in the early fall. The problems book will contain sections on lettering as well as problems on every other phase of the work.*

THE MACMILLAN COMPANY

60 Fifth Avenue New York

McGraw-Hill Announces

a series of

ENGINEERING DRAWING SHEETS

to be used with the new fifth edition of

FRENCH'S

ENGINEERING DRAWING

These sheets:

—make generally available an approved method of instruction, the preparation and production of which would be difficult for a single institution;

—are so flexibly arranged as to retain completely the individuality of the teacher, encourage the initiative of each student, and permit adjustment to varying aptitudes;

—provide an optional feature in the addition of simple illustrative problems in slide rule technique and estimation of areas and volumes. Thus, by the use of instructional means possible only with the printed sheets, the student's visualizing power is developed and his professional interest increased;

—utilize each lesson taught as instructional material in succeeding lesson;

—increase the value of the basic text and promote the student's personal mastery of the subject by study.

The sheets are faultlessly printed on Duplex paper, with carefully designed format, and they constantly emphasize style and quality to every student. The material is based on the teaching practice of The Ohio State University and the Carnegie Institute of Technology and has been arranged by Thomas E. French and H. M. McCully, who have embodied valuable suggestions of their colleagues in many other institutions.

The assured wide use of this series of sheets in conjunction with French's *Engineering Drawing* will make possible the publication of a very large edition, and thus permit the sale of material of the highest quality at a moderate price.

The first book of the series will be available for examination in May.

Send for a copy on approval

McGraw-Hill Book Company, Inc.

330 West 42nd Street **New York, N. Y.**

THE JOURNAL OF ENGINEERING EDUCATION

Published by the Society for the Promotion of Engineering Education

Published under the Supervision of the Publication Committee.
D. S. Anderson, C. C Williams, F. L. Bishop, Editor, University of Pittsburgh.
Published at Prince and Lemon Sts., Lancaster, Pa.

Entered as second-class matter at the Post Office at Lancaster, Pa., under the Act of March 3, 1870.

New Series
Vol. XXVI, No. 8. APRIL, 1936 Subscription Price, $3.00 per year. Single Copies, 50 cents

TABLE OF CONTENTS

The University of Wisconsin. L. F. Van Hagan 595
Results of the Letter Ballot on Engineering Degrees. O. M. Leland 607
The Five-Year Curriculum in Engineering. J. A. Orr 614
Remodeling the Engineering Curriculum to Meet the New Economic Conditions. J. A. Correll 620
The Four-Year Curriculum Should Be Retained. P. S. Biegler 626
Fifty Years of Engineering Education. Jasper O. Draffin 635
The Influence of the Education Departments on Engineering Education. Franklin O. Rose 643
Teaching the Course in Technical Writing. Carl Naether 647
What a Youngster Thinks of Engineering Education. J. R. Connelly 653
The Place of Photoelasticity in Engineering Instruction. Max M. Frocht 656
T Square Page 669
Civil Engineering Division 670
Employment Service 672
S. P. E. E. Emblem 672
New Members 673
American Engineering Council 674
New Committee Appointments 675
College Notes 676
Sections and Branches:
Illinois-Indiana 678
Middle Atlantic 679
Texas 680
Report of Conference on English 681
Book Reviews 684

HEADQUARTERS OF THE SOCIETY

UNIVERSITY OF PITTSBURGH, PITTSBURGH, PA.

OFFICERS OF THE SOCIETY, 1934–35

President

D. S. ANDERSON, Tulane University, New Orleans, La.

Vice-Presidents

P. H. DAGGETT, Rutgers University, New Brunswick, N. J.

S. B. EARLE, Clemson Agricultural College, Clemson College, S. C.

Secretary

F. L. BISHOP, University of Pittsburgh, Pittsburgh, Pa.

Treasurer

W. O. WILEY, John Wiley & Sons, New York City

Assistant Secretary

NELL MCKENRY, University of Pittsburgh, Pittsburgh, Pa.

THE UNIVERSITY OF WISCONSIN

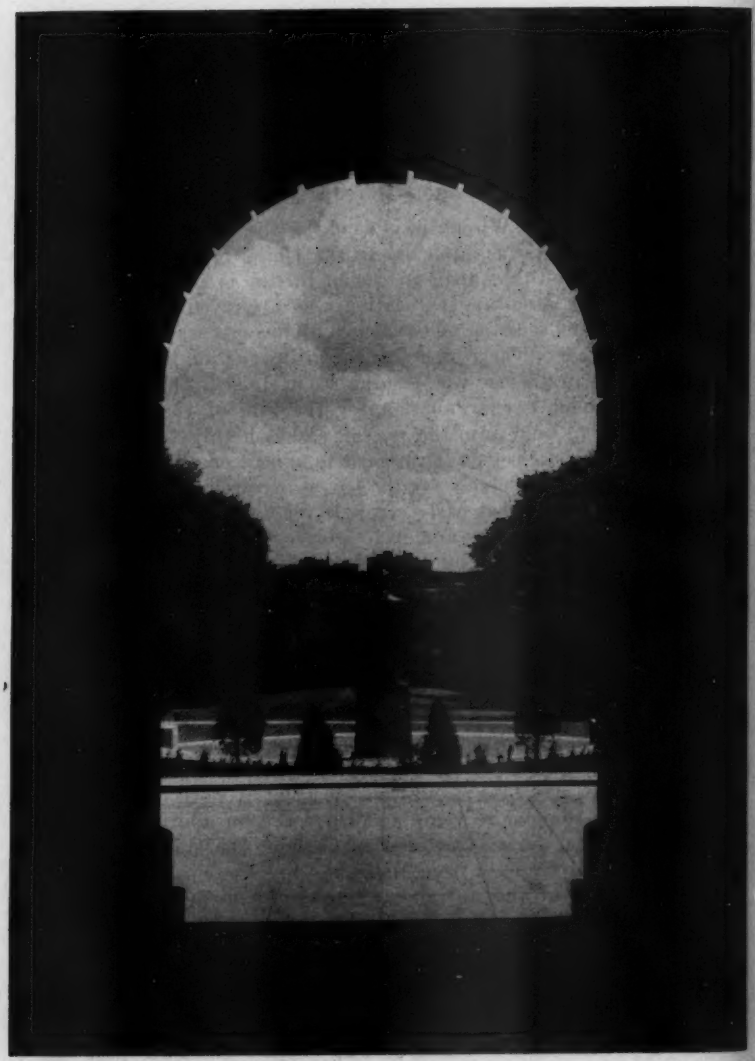
By L. F. Van Hagan

Professor of Railway Engineering

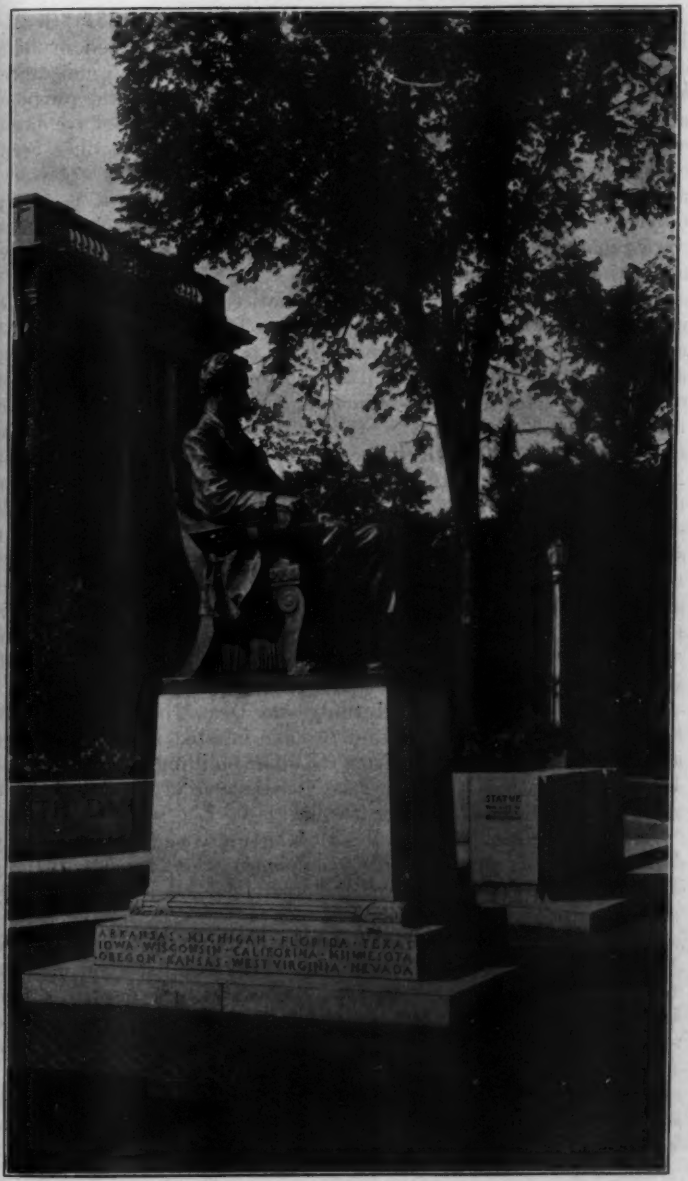
The University of Wisconsin is as old as the state in which it is located. Wisconsin was admitted to the Union on May 29, 1848, with a Constitution that made provision for the creation of a state university. The necessary legislation was approved on July 26, 1848, and the first meeting of the Board of Regents was held in October of that year. The University began instruction in February, 1849, and the first class was graduated in 1854. This event occurred just about twenty years after the first of the stream of settlers began to pour into the region, and is highly significant of the attitude of those settlers in regard to education at a time when they had to struggle fiercely for the barest necessaries of life. The university shared in that early struggle for existence; it was close to the people of the state and has endeavored consciously to perpetuate that closeness to and understanding of Wisconsin men and women.

Among the many features that have worked to the advantage of the University of Wisconsin, undoubtedly one of the most important has been the concentration of its various schools and colleges on one campus. Letters and Science, medicine, law, engineering, and agriculture are all brought together to form a single compact group united in interests and governed as a unit. The Extension Division, it is true, maintains what is called the Milwaukee Center, where students may take a full-time program of work covering the freshman and sophomore years and there are, in addition, numerous experimental farms scattered throughout the state, but these activities are all directed from Madison.

The campus of the university extends for two and one-third miles along the shore of Lake Mendota and contains more than one thousand acres of land. The terrain is hilly and well wooded. The one hundred and ten buildings of the university center about Bascom Hall, which crowns a hill that rises one hundred feet above the waters of the lake near the eastern limits of the campus. Bascom Hall faces the Capitol, which crowns another eminence just one mile farther east. In between the two buildings lies the older portion of the City of Madison, which has now spread so that it surrounds the campus.



THE OPEN DOOR OF WISCONSIN



THE LINCOLN TERRACE

The earliest buildings on the campus, North Hall (1851), South Hall (1855), and Bascom Hall (1857) were constructed of buff sandstone from local quarries and designed in Italian renaissance style. Both the style and the color were well suited to the purpose and the setting of the buildings, and in general both have been adopted in the design of the many buildings that have since been erected. The sandstone is weak and porous and makes necessary an extremely simple treatment of exteriors in which it is used; otherwise it weathers severely under the action of frost. For this reason many of the buildings are faced with a buff brick that closely approximates the stone in color.

Some of the buildings constitute noticeable exceptions to the general style and color scheme. Science Hall (1888), said to be one of the first steel-frame buildings in the country, the Armory, and the Law building stand out among the other buildings because of their red color and their Romanesque style. The first two are faced with red brick and the other with Superior sandstone. The Law building (1893), which receives constant criticism because of its lack of harmony with its surroundings, is said to represent the taste of President Adams, who was a great admirer of the Richardsonian Romanesque and insisted upon having an example of that style among the university buildings. Unfortunately, the style, while highly popular in the days of "brown-stone fronts," does not arouse the same enthusiasm to-day that it did when it was an innovation. The incident is mentioned to illustrate one difficulty in adhering to a long-time policy of architectural treatment in university buildings.

Another opponent to uniformity was Dean Henry of the College of Agriculture, who is said to have insisted upon having the agricultural buildings differ from the other buildings on the campus. He permitted them to follow the Renaissance style, but insisted upon having them of a different color.

The library is, perhaps, the most attractive of the university buildings. It is in the classic renaissance style, faced with grey Bedford limestone. It houses the university library and library and museum of the state historical society.

Out on Observatory Hill, locale of a current song hit, stands the Washburn observatory, built in 1878, and a small student observatory. The principal telescope is of the refracting type with a 15.6-inch aperture. The energies of the staff are directed chiefly to research, photo-electric photometry of stars receiving much attention at the present time.

From Observatory Hill, one may see lying below on the lake shore the red-roofed dormitories and refectory which provide accommodations for five hundred men students. Women students

have a group of three buildings devoted to their use. Two of the buildings are dormitories and one houses a gymnasium, a swimming tank, and provides offices and meeting rooms for various other activities. The women's group of buildings lies at the corner of Park Street and University Avenue. Both men and women students share the Memorial Union building.

A feature of student life at Wisconsin is the equality and good will that exist between the men and women students. They work together amiably in classroom and laboratory, are on an equal footing in campus politics, and share their social relaxations. Women take an active part in the work of the Memorial Union, and a woman student is president of the present senior class, although women voters are outnumbered two to one on the campus. Perhaps the high rating of women at Wisconsin accounts to some extent for the fact that the percentage of out-of-state students is higher for women than for men, being twenty-three per cent for women as against thirteen per cent for men. The number of students from foreign countries is less than one hundred, and the negro students can probably be numbered on one hand. The student body is predominantly Wisconsin-born.

Wisconsin alumni were among the first in the country to appreciate the possibilities of exploiting for the benefit of the university the discoveries made in the university laboratories. The Wisconsin Alumni Research Foundation is the custodian and protector of a number of valuable patents, the most valuable of which is the Steenbock process for irradiating foods. Through the earnings from these patents, the Foundation has been enabled to assist research at the university during the years of depression with substantial grants of funds.

The University Club at Madison is another feature of the university that differs considerably from the usual type of faculty club. It was organized in 1907 under the active leadership of President Van Hise, upon the basis of voluntary membership and entirely free from university support or control. The present large club house was built a section at a time as funds were available. A few years ago the property was deeded to the university to be used as a faculty club open to both men and women. The membership, however, still continues upon a voluntary basis. Many of the faculty members live at the club. Its facilities are used to capacity for committee meetings. It also offers each year an attractive program of social events.

This description of the University of Wisconsin makes no pretence of covering those features of the school which are common to all institutions of its kind and class; it is rather an attempt to point out very briefly those features which characterize Wisconsin and

PRESIDENT GLENN FRANK

LIBRARY

which differentiate it in greater or lesser degree from her sister universities.

LOCAL COMMITTEES FOR 44TH ANNUAL MEETING OF THE SOCIETY AT THE UNIVERSITY OF WISCONSIN, MADISON, JUNE 23–26, 1936

General Committee

F. E. Turneaure — F. M. Dawson — B. G. Elliott

Registration

J. M. Dorrans, *Chairman*
N. H. Ceaglske
H. B. Dake
R. R. Benedict
T. P. Colbert
F. A. Mattka
H. T. Avey
R. N. Schumann
Bert Bridge
R. R. Bell
O. N. Olson (Marquette University)
T. J. Riebeth (Marquette University)

Reception

A. V. Millar, *Chairman*
E. R. Maurer
G. L. Larson
Edw. Bennett
C. M. Jansky
O. L. Kowalke
L. Kahlenberg
N. F. Hollander
L. R. Ingersoll
L. O. Hanson
R. S. McCaffery
O. C. Cromer
F. O. Griffith
H. D. Orth
Edw. Anderson
W. J. Fuller
E. R. Jones
F. A. Kartak (Marquette University)
H. Formmelt (Marquette University)

Publicity

L. F. Van Hagan, *Chairman*
H. Ruf
W. J. Hebard (Marquette University)
A. S. Kolpf (Marquette University)

Transportation, Parking, Special Trips

J. F. Oesterle, *Chairman*
R. A. Ragatz
J. R. Price
L. S. Baldwin
S. A. Witzell
D. W. Nelson
G. J. Barker
O. O. Hougen
A. F. Gallistel
L. J. Markwardt
J. E. Schoen (Marquette University)
W. D. Bliss (Marquette University)

Information and Signs

H. E. Pulver, *Chairman*
L. E. A. Kelso
W. S. Cottingham
Thos. Puddester
D. J. Buroker
J. D. Livermore
R. Worsencroft
L. F. Hillis
H. E. Grant

Entertainment

G. F. Tracy, *Chairman*
K. G. Shiels
E. D. Ayres
R. Hartenberg
M. S. Nichols
L. H. Kessler
P. H. Hyland
R. E. Johnson
G. W. Washa

Conferences and Exhibits

J. W. Watson, *Chairman*
H. F. Janda
F. E. Volk
J. W. McNaul
G. C. Wilson
G. F. Young
C. F. Peters
R. S. Owen
G. Walton
F. W. Duffee
K. F. Wendt
A. J. Krombholz
Glenn Koehler
Phillip McCaffery
H. D. Orth
J. J. Peot
C. W. Thomas
H. N. Calderwood
H. B. Wahlin
George Hunt
L. J. Markwardt
W. H. Twenhofel
Jos. Zapata
I. S. Sokolnikoff

Housing and Regular Meals

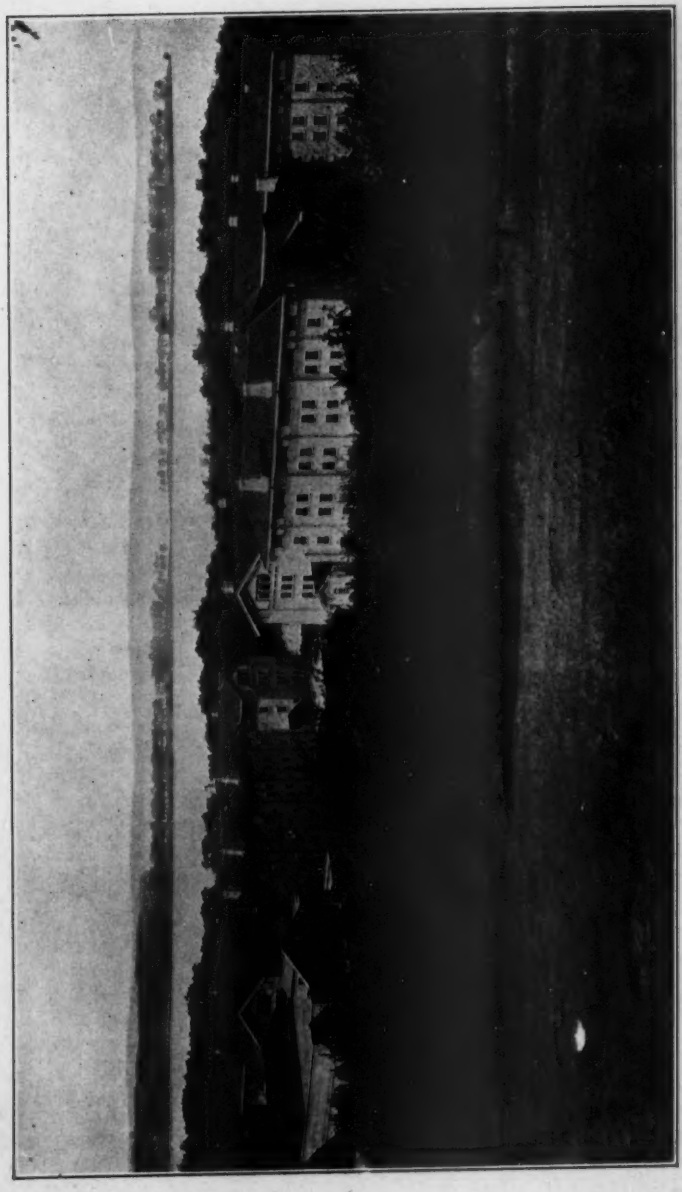
M. O. Withey, *Chairman*
R. A. Rose
L. C. Larson
F. A. Maxfield
R. W. Fowler
J. B. Kommers
J. J. Novotny
H. J. Kubiak

Banquet

J. D. Phillips, *Chairman*
E. R. Shorey
R. J. Roark
P. G. Ellis
J. G. Van Vleet
L. A. Wilson

Dinner for Council

B. G. Elliott, *Chairman*
W. S. Kinne
E. T. Hanson
A. T. Lenz



MEN'S DORMITORIES

THE WISCONSIN UNION

Committees for Ladies

General Chairmen

Mrs. A. V. Millar Mrs. P. H. Hyland

Reception

Mrs. K. G. Shiels

Wednesday Luncheon

Mrs. L. F. Van Hagan

Thursday Afternoon Entertainment

Mrs. Edw. Bennett

Thursday Evening Entertainment

Mrs. J. Watson

Care of Younger Children

Mrs. R. Benedict

Care of Older Children

Mrs. E. D. Ayers

RESULTS OF THE LETTER BALLOT ON ENGINEERING DEGREES

By Dean O. M. Leland

University of Minnesota
Chairman of the Committee on Engineering Degrees

The Committee on Engineering Degrees was appointed in 1933 and submitted its report at the Ithaca meeting of the Society in June, 1934. Upon the recommendation of the Council, this report was carried over to the 1935 meeting at Atlanta with the provision that it would be brought to the attention of the membership by publication in the Journal in advance of the meeting, together with supporting statements and explanations. This report appeared in the Journal for April, 1935.

At the Atlanta meeting the report of the Committee was given a place on the program and action was taken referring the question of adopting the recommendations to a letter ballot of the Society. The ballots were sent out to the entire membership by the Secretary, under date of October 10, 1935, with the following letter, including a copy of the Committee's report.

October 10, 1935.

On Recommendation of the *Committee on Engineering Degrees*

Society for the Promotion of Engineering Education

At the Atlanta meeting of the Society in June, 1935, it was voted to submit the recommendations of the Committee on Engineering Degrees to the membership of the Society for *letter ballot.*

For the information of the members who were not present, the report of the Committee is presented herewith, and reference is made to the explanatory article by the chairman, Dean Leland, which was published in the April, 1935, number of the Journal of Engineering Education. The original recommendations of the Committee were combined into three, at Atlanta, as shown on the attached ballot.

Twenty-five years ago, this Society approved for the bachelor's degree the form, Bachelor of Science in Civil Engineering (B. S. C. E.). That action still remains. Nevertheless, a large number of colleges still use other forms, especially Bachelor of Science without reference to engineering. Approval of the present recommendations would mean the omission of the words " Science in," from the above form approved by the Society years ago and the consequent simplification from B. S. C. E. to B. C. E. This approval would in no way require any institution to adopt this form.

Every member is urged to fill out the attached ballot and return it to the Secretary without delay in order that representative action may be obtained. Ballots received after January 31, 1936, will not be counted.

(signed) F. L. BISHOP,
Secretary.

REPORT OF THE COMMITTEE ON DEGREES IN ENGINEERING, S. P. E. E.

Although a standard system of engineering degrees has been sought by this Society for many years, and three separate committees previous to this one have considered the question and submitted reports, in 1910, 1918, and 1920, a wide variation in practice still exists. In each case the committee has recognized the desirability of a uniform system and has hoped that a further consideration of the subject would bring about the desired result. The report of 1920 concludes: "Although our committee has not been able to reach unanimous opinions on the above points, we recommend the standardization of degrees given in engineering by the various American colleges, as far as may be practicable."

Using civil engineering as the typical example with the understanding that other branches such as mechanical, electrical, chemical, mining, etc., would be used in a corresponding manner, the following forms of the first, or bachelor's degree in civil engineering are in use:

Bachelor of Arts,
Bachelor of Science,
Bachelor of Science in Engineering,
Bachelor of Science in Civil Engineering,
Bachelor of Engineering,
Bachelor of Civil Engineering,
Civil Engineer.

Since 1920, significant actions have been taken which indicate a tendency to compromise upon an intermediate form. Several colleges have abandoned the degree of bachelor of science in civil engineering or the degree of civil engineer for bachelor of civil engineering. In 1933, a conference of representatives of engineering schools in the State of New York and the State Board of Examiners of Professional Engineers, in conjunction with the State Education Department, went on record in favor of the use of the degree, bachelor of civil engineering, with corresponding forms for the master's and doctor's degrees. Therefore, the present committee took up its work with a reasonable prospect of success.

The committee unanimously approves the following *principles* as a basis for all earned collegiate degrees in the field of engineering:

(*a*) Each degree should include the word bachelor, or master, or doctor, in order of advancement. (These are recognized forms in general use by colleges.)

(*b*) Each degree should include the name of the particular branch of engineering in which the major work is taken. (The professional nature of the degree is thus made evident.)

If the major work is in general scientific and fundamental subjects related to engineering but not primarily in a single professional field, the word *science* may appropriately be used, as bachelor of science, or bachelor of applied science.

In accordance with these principles and after careful consideration of the question in all of its phases and its historical background, the committee submits the following plan and unanimously recommends its approval by the Society, with the understanding that action in conformity with the plan is optional on the part of any institution:

(1) The bachelor's degree resulting from the completion of a professional curriculum in engineering should be of the type, Bachelor of Civil Engineering (B. C. E.).

(2) The master's degree in engineering should be of the type, Master of Civil Engineering (M. C. E.).

(3) The doctor's degree, in course, in engineering should be of the type, Doctor of Civil Engineering (D. C. E.).

(4) For curricula in general scientific or fundamental engineering subjects not primarily professional in character, the degree bachelor of science is appropriate, to be followed logically by master of science and (or) doctor of science or philosophy. (Applied science may be used if preferred.)

(5) The professional degree, Civil Engineer, etc., should be abandoned by educational institutions, both as an earned degree and as an honorary degree.

(6) Honorary degrees in engineering should be limited to the two forms, Master of Engineering (M. Eng.) and Doctor of Engineering (D. Eng.). Neither should be used in any other sense than as an honorary degree.

Respectfully submitted,
FRED E. AYER, University of Akron,
GEO. W. CASE, University of New Hampshire,
S. B. EARLE, Clemson College,
LOUIS MITCHELL, Syracuse University,
GEO. C. SHAAD, University of Kansas,
O. M. LELAND, University of Minnesota,
Chairman.

BALLOT

(To be filled out, detached, and returned to the Secretary, F. L. Bishop, University of Pittsburgh, Pittsburgh, Pa., *not later than* January 15, 1936.)

Question: Should the following recommendations of the Committee on Engineering Degrees be approved?

1. (*a*) The bachelor's degree resulting from the completion of a professional curriculum in engineering should be of the type, Bachelor of Civil Engineering (B. C. E.).

Yes ☐ No ☐

(*b*) The master's degree in engineering should be of the type, Master of Civil Engineering (M. C. E.).

Yes ☐ No ☐

(*c*) The doctor's degree, in course, in engineering should be of the type, Doctor of Civil Engineering (D. C. E.).

Yes ☐ No ☐

2. Honorary degrees in engineering should be limited to the two forms Master of Engineering (M. Eng.)

Yes ☐ No ☐

Doctor of Engineering (D. Eng.)

Yes ☐ No ☐

and these should not be used as earned degrees.

3. The professional engineer degrees, such as Civil Engineer (C. E.), should be discontinued by educational institutions both as earned and as honorary degrees.

Yes ☐ No ☐

(Signature) .....
(Institution) .....
(Rank or title) .....

Results of the Ballot

Secretary Bishop reports the results as follows:

Question 1 (Degrees earned in course)		
(*a*) B. C. E., etc.	Yes 657 (=81%)	No 152
(*b*) M. C. E., etc.	Yes 650 (=81%)	No 150
(*c*) D. C. E., etc.	Yes 639 (=80%)	No 156
Question 2 (Honorary degrees)		
M. Eng.	Yes 666 (=85%)	No 116
D. Eng.	Yes 702 (=90%)	No 78
Question 3 (Discontinue "Engineer" degree)		
C. E., etc.	Yes 474 (=61%)	No 304

Total ballots received	813
Number of institutions represented,	160
Voters outside of faculties,	50

(Total membership, 2325)

A letter ballot of this Society has rarely, if ever, been resorted to in order to obtain a more general expression of the membership than is possible at an annual meeting. In this case, the proportion

of members voting is unusually large, thirty-five per cent of the entire Society. The attendance at the final business session of an annual meeting is seldom very large, probably less than two hundred at the outside. The significance of the present ballot, therefore, is outstanding as the results are more than ordinarily conclusive.

The first and second questions were divided into their component parts so that each member could vote upon each part independently of the others. Every member of the Society was given an opportunity to vote. All six of the separate recommendations were approved by substantial majorities.

The vote in favor of the three parts of Question 1 was *four to one,* giving the Society's approval to the sequence of *earned* degrees exemplified by Bachelor of Civil Engineering, Master of Civil Engineering, and Doctor of Civil Engineering.

The vote on Question 2, relating to the forms for *honorary* degrees in engineering, was about *eight to one,* approving the recommendations. The use of Doctor of Engineering (D. Eng.) as the honorary doctorate in the engineering field is very generally favored. The honorary Master of Engineering (M. Eng.) met with nearly as great approval.

Question 3 was carried by a vote of about *three to two,* in favor of the policy of discontinuing the use of the professional *engineer* degrees (such as C. E.) by the engineering schools, both as earned and as honorary degrees.

The principle of omitting the words "science in" from the Society's previous form bachelor of science in civil engineering, etc., adopted in 1910, leaves undisturbed the flexibility of application to all engineering or technological fields according to the preferences of the individual faculties. Thus, the question of expanding or reducing the number of different fields represented by separate degrees is not involved in this action by the Society. Its previous policy contemplated the use of these separate fields although many schools still use the single degree bachelor of science with no reference whatever to engineering or any other department of knowledge.

The degree bachelor of engineering has been proposed for a general course in the fundamentals of engineering without special reference to any particular branch of the subject. The Committee has suggested for this purpose the degree bachelor of general engineering or bachelor of applied science in the hope that bachelor of engineering would not be used on account of its association with the honorary degrees master of engineering and doctor of engineering. A number of schools have curricula in general engineering in addition to the usual civil, electrical, etc. It must be admitted,

however, that bachelor of engineering is consistent with the basic principle advocated by this Committee, although bachelor of general engineering (B. Gen. E.) would be preferable.

Obviously, the present necessity for distinguishing among the various abbreviations for the branches of engineering must continue. Actually there is general unanimity in the use of these abbreviations. Many years ago, it became necessary to distinguish between mechanical and mining engineering. M. E. was accepted for mechanical and Min. E. for mining engineering. Similarly, it is necessary to use more than the single initial letter for other branches and this practice will be extended as new fields are developed and come into professional recognition. We now have, for example, Aero. E., Agr. E., Arch. E.; C. E. (civil), Ch. E. (chemical), Cer. E. (ceramic); M. E. (mechancial), Min. E., Met. E. (metallurgical);—and it is logical to use such forms to avoid ambiguity.

The adoption of the master and doctor of engineering for honorary degrees does not carry a recommendation that honorary degrees be awarded. Many schools never award such degrees under any circumstances. By this action, however, the Society approves the use of these two forms for this purpose when engineers are to be thus honored. Comments accompanying some of the ballots indicated that those members voted against the use of these two degrees to express their disapproval of the award of any honorary degrees at all. That question was not involved in this ballot.

Similarly, some members opposed the abandonment of the professional engineer degree by the colleges with the idea that this would involve the discontinuance of any degree based partly or entirely upon professional experience after graduation. Here, also, the Committee has endeavored to emphasize that its recommendation applied only to the use of this particular form of degree and not to the basis upon which it or some more suitable degree would be awarded.

To clarify the position of the Committee in this matter, two uses of a master's degree have been suggested as appropriate substitutes for the professional engineer degree as awarded by certain schools to their alumni upon a post-graduate or post-scholastic basis. In the first case, if the engineer degree requires post-graduate study either in residence or in absentia, the regular master's degree, as master of civil engineering, could be used in its stead with such allowance, if any, for experience and thesis as might be determined by the faculty concerned. In the second case, where the engineer degree is now awarded primarily for experience and professional achievement, the master of engineering could be used, either as an honorary degree or as a professional degree. The honorary char-

acter of the degree would be preserved especially if ten or fifteen years of experience were required instead of the three or four years now used for the engineer degree. On the other hand the M. C. E. could replace the C. E. as a *second* degree in *all* cases without much deviation from present practice and this will undoubtedly be carried out by some institutions. It would seem that these possibilities would provide a suitable master's degree for the cases in which the engineer degree is now used as a second degree.

In the light of this action by the Society, the faculty of each engineering school is justified in examining its degree practice to determine whether or not it wishes to make a change. The Society's approval of these recommended forms should afford such authority as may be desired by any faculty wishing to adopt any or all of them. Undoubtedly special circumstances exist at certain institutions which may make it difficult or inopportune to change degrees immediately. It is a gradual process. Nevertheless progress can be made and each school will act for itself. The adoption of the recommended bachelor's degree, only, leaving the others for future consideration, would be an important step towards unification.

THE FIVE-YEAR CURRICULUM IN ENGINEERING*

By J. A. ORR

Texas Agricultural and Mechanics College

At a national meeting of this Society at Niagara Falls in 1903, the late William T. Magruder suggested to a prominent member of the society that it might be well to extend engineering courses to five years. The reply he received was, "Young man, if you want to lose your job, just suggest a five-year course at your university." So, Gentlemen, I shall immediately play safe by stating that I hold no great brief either for or against a five-year course. In my opinion the engineering colleges should offer, in addition to the usual course completed in four years, courses designed to be completed in five years and others in six years. The five-year course in engineering has been a controversial subject for more than fifty years, and many men have presented competent studies on the subject.

Even as early as in the middle eighties, Washington University aroused considerable controversy concerning engineering curricula by inaugurating a five-year course. It was afterward abandoned, for what reason I am uninformed. The State University of Iowa provided five- and six-year courses in engineering in 1908. Sibley College offered five-year engineering courses in 1909. The University of Minnesota offered only a five-year course in the fall of 1910. In 1911 the University of Missouri abandoned all four-year courses in engineering and substituted five-year courses. Several other colleges and universities made similar changes in their curricula in later years. In fact there was a decided trend toward five-year courses in Southern and Mid-Western universities prior to the adverse report of the S. P. E. E. committee of 1927.

The agitation for five-year courses in engineering seems to be a fad. The subject has been attacked from every angle and still we reach no conclusion. In fact there seems to be little agreement as to what will be done with the fifth year when and if we get it. One party says we should give our students a more liberal education, by combining the humanities and the social sciences with engineering. Another states that our four-year period is much too short a time for the subjects covered and that no new courses should

* Presented at the meeting of the Texas Section at the Texas Technological College, April 19, 20, 1935.

be added, even if a fifth year is secured. Still another says that we must have five-year courses because the high schools do not prepare the students well enough, and that we need an extra year in order to give the freshman the foundation that he should have received in high school. Another merely states that an extra year is needed for "broad cultural" courses.

There are, however, many advantages and disadvantages to a five-year course that are evident to all of us, though it is difficult to evaluate their relative importance. Personally, I believe that the advantages of a longer curriculum in engineering outweigh the disadvantages of such a course, and I, therefore, advocate in addition to the present four-year course a five-year, or longer, course in engineering for at least these four reasons:

First, because the high schools are no longer furnishing their graduates with the necessary foundation in mathematics for an engineering education.

Second, because the present four-year course is more than the average student can assimilate in that period of time.

Third, because the longer courses could be used to separate the indifferent and weak students from the more ambitious students.

Fourth, because more cultural, or humanistic, subjects could be included in the engineering curricula.

Most people, particularly those who teach engineering subjects, will agree that the great majority of the present-day high school graduates are woefully weak in the subjects that are essentially prerequisite to admission to an engineering course.

As an example of this weakness let us consider an incident that occurred at the Texas A. & M. College. Near the beginning of the school year of 1933–1934 Prof. John Mitchell of the Mathematics Department of the College gave a short test to a group of representative freshmen engineering students from all parts of the state and representing many high schools. This test consisted of the following three problems:

1. Add $2\frac{1}{2}$ to $4\frac{1}{5}$.
2. Multiply $3\frac{1}{4}$ by $5\frac{1}{2}$.
3. Divide $6\frac{1}{2}$ by $3\frac{1}{4}$.

Of the twenty-six boys who took this test only thirteen solved all three problems, and of the remaining thirteen only nine could solve two problems. Two boys were able to solve one problem and two boys could solve none.

The trouble with this group was not a lack of intelligence, for most of them had made fairly creditable grades in their so-called "Intelligence Tests" at the opening of the semester. Practically

all of their trouble was an insufficient amount of training in mathematics in the high school. Most of the students probably knew how to deal with fractions when they entered the high school, but they had so little contact with mathematical subjects in the high schools that they lost the knowledge of arithmetic that they obtained in the grade schools.

Surely Dr. A. Lawrence Lowell's statement that there is a lot of knowledge in the colleges, "since the freshmen bring in so much and the seniors take away so little," is even more applicable to the Texas High Schools. Perhaps we are over-critical of the high schools. Possibly the high school teachers are correct in the type of training they are giving their students, for after all more than eighty per cent of their students never enter college, and only a small percentage of those who do enter take an engineering course. Nevertheless, we do know that the applicants for entrance into engineering colleges at the present time are without the knowledge of mathematics that high school graduates of earlier years had, and we know that if these applicants are accepted it will be necessary for them to devote a considerable part of their first year to preparatory subjects.

It may be possible to justify the high schools in not requiring their graduates to take certain subjects that have been considered as essential to any engineering applicant, but to my mind, it is impossible to justify any college, or university, in trying to crowd into an already overly crowded four-year curriculum, subjects that have heretofore been taught in the high schools. A five-year course is the one way in which preparatory courses can be added without a corresponding loss in the more advanced technical courses.

For eighty years, or more, engineering degrees have been conferred upon the men who have completed a designated four-year curriculum. Four years is still the time required to obtain a degree. No more time is required in 1935, than was required in the early half of the nineteenth century. Does it not seem absurd that with all of the development that has occurred in engineering theories and practices during the past three or four decades that no more time is necessary to teach engineering today than was needed in 1840 or 1850? Surely our teaching methods have progressed by leaps and bounds.

In an S. P. E. E. report of 1927, statistics are given which show that the percentage of students admitted to thirty-eight representative institutions during the five-year period of 1899–1900 to 1903–1904 who graduated in the succeeding period of 1902–1903 to 1906–1907 was 43.5. The percentages of eliminations for the succeeding five-year periods are 57.2, 58.1, 62.4 and 61.6 for the

years 1923 and 1924. If the delayed students are added to these figures, the percentages are increased to about 72, or in other words, only 28 per cent of those who are admitted in the normal four-year period. The report also shows that more than 53 per cent of these eliminations are caused by scholastic difficulties. 35 or 40 per cent of the students who enter college are dropped as "failures."

It is entirely probable that with better foundation work many men of this failing group could be trained as technicians to carry on routine engineering work. A number of poor students manage to struggle along in classes of capable students and finally pull through and are offered to the world as engineers. These men are not, and will never be, capable of the highest type of engineering work, and there should be a distinction between them and the able students.

Would not a combination of four-, five-, and six-year courses solve this problem? The four-year course could consist of the elementary engineering subjects usually covered in the first three years of the conventional four-year curriculum. This change would permit the introduction of required preparatory courses in the first year, and liberalizing courses in the following three years. The student upon completion of such a course could be given a certificate and a license to practice as an engineering technician—by no means should he be called an engineer, nor should he be allowed to practice as an engineer. His work should be limited to that of an inspector, or engineering foreman.

The five-year course should include all subjects now covered in the present four-year course, plus a few additional liberalizing subjects. The course should be designed to prepare engineering practitioners, who carry on the usual engineering operations. Those taking such a course should be required to prove their ability either by rigid special examinations, or by making a minimum number of grade points on the previous four years' work. The requirements should be such as to permit even smaller percentage of graduates than the 28 per cent that now graduate, for many of our present graduates would make better hosiery salesmen than engineers. The student upon completion of this course should be given a Bachelor's Degree.

The six-year course could be restricted to those students who had satisfactorily completed a five-year course, and had shown exceptional ability in original design or research. The student upon the completion of this course could be given a Master's Degree.

A large number of our young engineers "snort" at the very idea of cultural courses being given a prominent place in our engineering curriculum, but I am inclined to believe that those very

"snorts" may be the cause of the patches so prominent in the seat of their pants. Many engineers have not realized that cultural courses have a real monetary value, and capable engineers have failed to obtain desired positions or win arguments with city councils just because of inability to talk or write intelligently, or interestingly. Often this inability is due to the fact that these men were so engrossed in technical subjects in college that history, literature, music, psychology, foreign languages, public speaking, etc., did not seem important. As they grow older, however, these things assume their true value. Aside from the fact that such knowledge actually increases earning capacity, it is a source of enjoyment and pleasure. Charles Darwin, in his seventieth year said, "If I had my life to live over again, I would make it a rule to read some poetry and listen to some music at least once every week; for perhaps the parts of my brain now atrophied would thus have been kept alive through use. The loss of these tastes is a loss of happiness."

It has been suggested by those favoring the four-year course, with few prescribed humanistic subjects that a development in cultural background could be forced upon many engineers by a requirement of a general cultural knowledge in addition to certain technical ability before they could become members of any of the National Engineering Societies. Undoubtedly such a procedure would be of value to the engineers, but those favoring the five-year plan insist that there is a virtue in the formation of correct habits of study and thought, which are more easily acquired in youth, under the direction of an able teacher.

William E. Wickenden, former President of the S. P. E. E., delivered an address in Madison Wisconsin, on July 6, 1933, on "Social Science in Engineering Education." A part of his talk is particularly apropos to this subject and I shall now quote him:

> I have indicated my belief that the engineer must reckon more largely with the social sciences and that they must have a more generous place in our teaching. May I add the belief that they should be taught by men whose major interest is in human beings and society and not by engineers. Our students need to know the controversial nature of these subjects and the conflicts of human interest which they involve. They need an organic conception of society and some perspective of its evolutionary character to save them from thinking of the existing social organization as being final, static, and inevitable. They need to know the limitations of all social controls, and most of all to be saved from the most dangerous of all forms of ignorance—that naive innocence which tempts the tyro to rush in where experts fear to tread. But social studies for the engineer are not mere cultural veneer; they need to be tied functionally to his sphere of work, and this aspect of the problem is still largely unsolved.

Experience has shown that the longer curricula have not as yet proved satisfactory. Prominent schools have adopted five- and six-year courses and have had to drop them, for they could not compete with schools of equal prominence that held to the four-year course. It would seem that there is little possibility of a long curriculum proving successful until all of the important schools of the nation make a concerted move for such a course. Unfortunately, just now the economic conditions are such that many students can ill afford an extra year in college, and it is also true that our state legislatures are in no mood to furnish the additional funds necessary to finance the longer curriculum.

For these reasons I believe that the "Five-Year Curriculum" can be no more than a worthy and interesting subject for debate—at least for the next few years.

REMODELING THE ENGINEERING CURRICULUM TO MEET THE NEW ECONOMIC CONDITIONS *

By J. A. CORRELL

Professor of Electrical Engineering, University of Texas

For years engineering educators have recognized that one of the grave faults in most plans for professional engineering education is that all types of students are forced through more or less the same mould regardless of their individual abilities and preferences. It is true that some latitude has been allowed through electives or group options but these have been largely subject options and not functional options. The criticism can be substantiated, in general, that our courses are too technical for the best interests of a large number of students but not technical enough for a few. The larger number of students are required to devote, to the mastery of technical theory, time that could be spent more profitably on a broader training in economics, business and related subjects. On the other hand a small number of students should devote more time to mathematics, the pure sciences, and the theoretical and technical phases of their profession than is possible with the present undergraduate curriculum. Neither group is offered the best facilities for the full development of their natural abilities.

Some attempts have been made to divide the curriculum along functional lines but most schools have adhered rather closely to the traditional type of curriculum and have sought to justify this by the fact that, in the past they have had no difficulty in placing their graduates and by the argument that the training obtained in a good engineering course is an excellent preparation for any walk in life. This last statement is still correct but changed economic conditions have forced us to a more critical study of the situation. There are no longer jobs for all and it now appears that industry may never again be able to absorb all engineering graduates. In the future there will be some demand for the best trained technical men, a larger demand for the commercial and business types, and no place at all in industry for the lame duck.

These conditions have resulted in much discussion in the meetings of this organization and in the technical press as to the proper

* Presented at the meeting of the Texas Section at the Texas Technological College, April 19, 20, 1935.

steps to take to bring the curriculum of our engineering schools in line with the needs of industry. The major problem arises, not in connection with the treatment of those students who show early in their college career that they lack either the natural ability or the preparation necessary to do creditable work, but in differentiating between those who are interested in and qualified to do work of scientific and technical nature and those of equal mental ability who possess the personality and wide variety of interests which can more profitably be directed toward administrative work in the field of engineering. These two groups not only have different objectives within the separate divisions of electrical, mechanical and civil engineering, but course content and methods of treatment that hold the interest of one group often is boring and irksome to the other.

To differentiate between the technical and administrative groups curricula have been offered combining business and engineering courses. These General Engineering or Industrial Engineering degree groups have, in general, not proved satisfactory. They are neither business nor engineering, neither fish, fowl, nor good red herring. They are in the nature of hybrids and, as is frequently the case with hybrids, seem to inherit the weaknesses of both parents and the virtues of neither.

Mr. L. L. Morrow proposes the creation of a school or college separate from engineering and business to administer a new type of course ". . . based on applied science, economics and psychology with electives in the humanities, in accounting, in banking, and in business law." This course would be broader than the present engineering courses but more definitely scientific than the present business courses and with pronounced accent on the engineering method and point of view. The companion technical engineering course would be narrower than the present courses containing less, rather than more non-technical subjects. Because of the objectives of this latter course, as well as the high standards in technical ability required for the proposed rigorous treatment of subject matter, only a small number of selected students would be admitted to the engineering college, while the bulk of the students now enrolled as engineers would be transferred to the new college.

There are many objections to this plan. It calls for two separate and distinct colleges with two levels in the engineering courses offered, as well as the added financial burden of two administrative organizations. The college requiring the greater expenditure for faculty and equipment would have the smaller number of students, and of course the greater cost per student. In fact it would be almost impossible to maintain such a proposed

technical college in most of the state supported schools because of this high cost per student. This would limit strictly technical training to a few well endowed private schools, and make this type of training too expensive for all but a fortunate few with financial resources sufficient to permit attendance at such schools. Many young men admirably fitted for such work would be denied the opportunity of obtaining a technical education. Students come to the colleges to-day with a fairly definite idea as to the particular type of engineering they wish to study; they want to be civil, electrical, mechanical or some other brand of engineers. They may not desire training as a highly technical specialist; but they certainly do want to pursue work along the line in which their major interest lies, and not in a general indefinite field of engineering.

The ultimate solution of the problem may be found in the much discussed plan of lengthening the engineering curriculum to five or six years. The first two years could then be devoted to a general course of study in the humanities and pure sciences, followed by the introductory engineering courses, and with the professional work concentrated in the last two years. This has long appealed to me as the most desirable program but it is not feasible until the engineering schools as a whole agree to the lengthened period. A five year program leading to the degree of B.S. in Electrical and Utility Engineering has been offered at the University of Texas for the past ten or twelve years and not more than four or five degrees have been conferred. This course includes all of the work required for the B.S. in E. E. degree with business and economic courses distributed through the five years. The small number of students selecting this arrangement does not mean a condemnation of the five year program, but it does indicate that a five-year plan can not compete with a four-year plan leading to a bachelor's degree. The student who plans on spending five years at the university, in most cases, prefers to work toward the master's degree.

The same general ground work for two general groups with latitude in options seems to be the best solution until it is possible to lengthen the period of study. As expressed in the S. P. E. E. Report, Vol. 1, "The same general grounding is desirable for both the technical and administrative activities in the engineering field, since the qualities of mind and habits of thought which are the most distinctive characteristics of the engineer are of more consequence in both realms than a book knowledge of either type of technique.

"Distinctive training for both the technical and administrative types of engineering activity should be provided but only after

an adequate grounding in science and engineering fundamentals has been laid. There should be relatively little differentiation of the two types of training in undergraduate engineering curricula.

"The auxiliary technical services and the minor supervisory and commercial activities associated with engineering are not recruited most effectively from the by-products of a program of professional training, nor are they adequately filled by using them as training assignments for men to be advanced rapidly to the higher types of engineering responsibility. These activities should be included in the objectives of a distinct, non-collegiate type of technical education, briefer, more intensive and more specialized than the programs of the engineering colleges."

At present, the University of Texas has no intention of offering the last mentioned type of training. This is the field of the junior colleges and of the trade schools. In order to discourage students whose best interests would be served by this type of course from devoting four years or more to a more-or-less wasted effort to obtain a college degree, those students admitted to the professional work should be required to show some degree of scholastic attainment beyond the mere passing of the required courses. We, therefore, require a student to make 810 grade points, a little less than a C average, in the required work of the first two years before he can register for any engineering course of junior standing. In this way it is hoped to eliminate most of those who are not qualified to do work of professional grade in time so that they may enter other fields of endeavor without much loss of credit. It will also result in a junior class more homogenous in mental ability.

In the electrical engineering course we now have 6 hours of electives in advanced courses. This is quite inadequate to meet the differentiation outlined above, and a complete revision of the course has been made. It was felt that an increase in electives alone was not an adequate solution as there would be no guarantee of a balanced program for either group. Two separate curricula have, therefore, been prepared, both leading to the degree of B.S. in E. E. The first two years are identical and consist of the fundamental sciences—mathematics, physics, chemistry; the general subjects—English, government, economics; and a minimum of pre-engineering courses such as drawing, mechanics, mechanism, shop laboratory and elementary electrical engineering. Only a few semester hours would be lost should the student transfer, at the end of his sophomore year, to some other school or college in the University.

At the beginning of the junior year each student will be required to select either the technical or the general option. This is to be in no sense a division between engineers and lame ducks

but the decision will be left to the student. The technical option is intended for those students who have shown more than average proficiency in mathematics and physics, but no qualifications, other than the general C average, is to be prescribed for admission to either group. Approximately the same courses in correlated engineering subjects, and the same basic courses in electrical engineering will be required of both. In these basic courses it is proposed to arrange separate sections for the two groups, and while the subject matter covered will be the same for all, a more rigorous, mathematical treatment of the subject will be given to the technical sections. The main difference in the required work is that the technical group will take six semester hours of advanced calculus and differential equations, a four hour course in exact electrical measurements and a three hour course in either power transmission or short circuit calculations, while the general group will substitute for these courses, a six-hour course in accounting and business law, three additional hours of economics, and a three hour course in the economic application of electrical machines. The technical group will have six hours of technical electives and three hours of general electives, while the general group will have ten hours of general elective.

Figure 1 shows the percentage of time during the first two

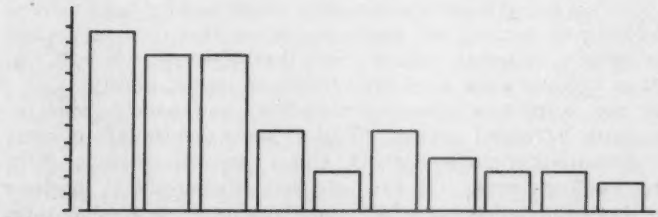


FIG. 1.

Freshman and Sophomore.

years that is devoted to the various subjects. Naturally mathematics predominates, but it is seen that the general subjects of mathematics, English, physics, chemistry and government occupy 72.3 per cent, while the pre-engineering courses occupy but 27.7 per cent of the student's time. Unless a man can do work averaging approximately C grade in these subjects, it is very doubtful if he has the preparation or ability to do creditable work in either group during the last two years.

Figure 2 shows the comparative time distribution during the last two years. The shaded areas for the general option and the unshaded are for the technical option. This shows that both courses are primarily electrical engineering but that there is a large enough difference in time distribution and point of emphasis to justify two separate curricula.

This plan is not ideal—it does not satisfy, fully, the needs of either group, but it is a step in the right direction. It offers more freedom of selection and yet guarantees a better balanced program

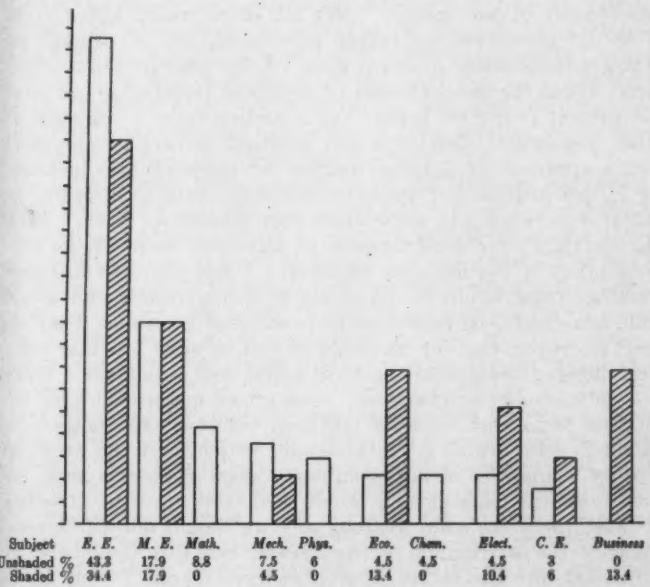


FIG. 2.

for the two classes of students, than does the present restricted course or the more liberal courses offering a large number of free electives. It is not as revolutionary as the proposal of Mr. Morrow but it avoids, in general, the objections to the more radical plan, and accomplishes the desired result within the limitations of a four year course in electrical engineering. When it becomes feasible to require five or more years for the first degree in engineering, this arrangement can be expanded to give greater differentiation between the two options.

THE FOUR-YEAR CURRICULUM SHOULD BE RETAINED *

By PHILIP S. BIEGLER

Dean, College of Engineering, University of Southern California

Few professors of engineering would not prefer a five-year curriculum to the present four-year standard, viewed purely from the standpoint of the teacher. Not all of us would agree upon what should constitute the longer curriculum but we should all want to graduate better educated men. A five-year program which included about the same amount of technical training as we have in the present four-year course but including more work such as English, economics, sociology, and political science would meet with the approval of a large number of engineering educators. Many college professors I have known always want to increase the technical requirements in work which they themselves teach. They would certainly have some measure of success in event of the general adoption of the five-year program. I feel that the five-year curriculum, then, would be something of a compromise and would include more technical as well as more cultural training. I do not believe, moreover, that all curricula should be alike but that each, while following the general pattern, might well retain some measure of individuality or character. One school might well have the reputation for a high order of technical training and another for excellent general training. This should better meet the needs of individual employers of our graduates; some want men with advanced technical training and others men more broadly educated.

I think there are many reasons why we should not all increase arbitrarily the curriculum to five years, but this should be an evolutionary process rather than a sudden change. That is, in fact, the principal object of this paper, to state some of the reasons for the retention of the four-year program leading to the academic degree in engineering, with advanced training for those who can afford it and at the same time show especial promise for the future.

Engineering and Medicine Contrasted

Much has been said about the success of the medical profession in reducing the supply of doctors by requiring a long and rigorous training, but there is a great difference in the scheme of practicing

* Presented at the meeting of the Pacific Southwest Section, Stanford University, December 27, 28, 1935.

medicine and engineering. Engineers do not practice individually to the same extent as doctors. Few of them "hang out their shingles" until after many years of experience in engineering work and only a small proportion of them finally practice as individuals. More commonly they work in large groups and develop themselves by contact with other engineers. They continue to study, either formally or informally, as their experience warrants or demands, whereas the doctor does not have the same day-to-day, hour-to-hour, opportunity to discuss his problems with other doctors.

By limiting the number of engineers it is quite probable that the remuneration for engineering services might be increased, but if the restrictions were as severe as in the medical profession I think the general public would suffer. In medicine the situation, as I see it, is that only the very rich and the very poor can get proper medical services. It is to the advantage of the general public to have engineers render all of those services which are best handled by men with engineering training.

Again, a very large proportion of engineering students come from families which are not well-to-do. They are usually self-supporting, at least in part, or depend largely upon families that can ill-afford to keep them in college for five years. The five-year program thus would entail a definite hardship upon them and many promising young men would be lost to engineering for this reason. The longer course would undoubtedly delay the time when the young engineer may marry and support a family, which is not desirable.

If we adopt the attitude prevailing in the medical profession, it would be our policy to limit more than we now do the number of young men in academic training for engineering, and to limit very much the number of practicing engineers. It has been my own experience, however, that the field for engineers expands as rapidly as the engineering enrollments increase and that it is no more difficult for our present-day graduates to find engineering employment than it was when I completed my academic training thirty years ago, barring, of course, two or three years of depression from which we are just now recovering.

We should bear in mind that all of our graduates will not attain positions of leadership. There will always be the draftsmen, the surveyors, and the operators who perform a very important service and a service which may be better accomplished by men with engineering training. It would be an ideal situation if all of these draftsmen became chief designers and chief engineers but, unfortunately for the ideal, those in responsible charge live for a long time and do not get out of the way fast enough for the young men coming up. Many are certain to remain in subordinate posi-

tions. For many the investment in a five-year college course would not be justified.

In many industries young engineers are expected to spend a year or more in the rough work of construction, maintenance, etc. In one rubber and tire company with which I am familiar young engineers are put into a training course for a year or so, during which time they go into any department when they may be needed in emergency, build tires or handle a truck in the shipping room. In this way they learn the routine business of the company very thoroughly. The rough work during this training period might be somewhat "galling" to the five-year man and he probably would be less satisfied to go through with such a program.

I am very much in favor of a strong cultural content in the engineering curriculum, but I feel that some men will benefit by it much more than others. The college period is a comparatively small part of an engineer's career and unless the student retains the desire to increase his culture, or understanding of the affairs of men outside of the technical field, he will never be what we call a cultured or well-rounded man. The exposure to a few more courses of a broadening nature through the five-year curriculum will not completely change a man's attitude toward life or profession.

Problem of Selection

Another disadvantage of increasing all engineering curricula to five years is due to the difficulty of selection. At the end of a four-year program we are certainly in a far better position to decide whether a young man would benefit by further study, and whether he should undertake advanced engineering work or the program advisable for those whose forte might be leadership or promise of executive capacity. It seems to me hardly worth while to require a great deal of humanistic work early in the curriculum. Engineering students seldom realize the importance of a broad education until the third or fourth year, or until they have had considerable exposure to the influence of the mature engineering faculty members.

If students should be required to take two years of Arts work before entering engineering, many would lose interest in the original objective. I recall an experience with a number of so-called "seal bearers" (boys who graduated from high school with scholastic honor) at the University of Southern California. Formerly a single member of the Arts faculty was adviser for all "seal bearers." Many of these promising young men never did reach the engineering classes until we succeeded in having the "seal bearers" who entered engineering advised by the engineering

faculty. If the program is to be five years in extent, I should prefer to have all five years under the control of the engineering college.

Post-College Education

In all of the large cities and industrial centers it is possible for engineers to continue their education after leaving the university campus. Many of the great industries, such as the large electrical manufacturing companies, have very definite training programs. For the few there are the advanced engineering courses, which in many ways are quite on a par with graduate courses offered by the colleges of engineering. To others are offered courses in economics and business, factory management, salesmanship, and the like. Many of these industries assist their young engineers financially in taking night courses of study in nearby universities. In our own institution our night classes for men taking advanced engineering work are larger than those in day-time courses. We find a steadily growing interest among engineers having full-time employment in late afternoon and evening classes. Thus for many young engineers even the formal education goes on after graduation.

We find that men who take university work after being out of college for a time are intensely in earnest about their work. When they encounter the actual need of further study the motive is far stronger than during undergraduate years. Late afternoon and evening classes given by the College of Engineering at the University of Southern California are, of course, of an engineering nature and satisfy the need for advanced technical training for a large number of men. While we engineers do not have the experience of teaching the cultural work so strongly recommended, it seems logical to conclude that, once the need of this work is fully realized, these men will undertake it with the same zest and energy as advanced engineering courses.

Undoubtedly the attitude of any college professor is more or less influenced by his own experience. Having lived my life in the electrical industries I have found a strong tendency toward the employment of four-year men, with a continuation of the training after graduation. Large numbers of civil engineers go into public service and again are associated with large groups of engineers. Others of you have undoubtedly quite a different experience and a very different point of view.

Attitude of Industry

With these thoughts in mind I have made some study of the attitude of employers of engineers in Southern California and I

shall present the results as fairly as possible. It has been said that one may find statistics to support almost any contention, and the value of the results depends entirely upon an unbiased presentation.

In choosing the names of men to whom we might send a questionnaire we picked out engineers when we felt that the engineer was largely responsible for the type of men employed. In other instances we deal largely with the employment managers. After selecting a list of addresses in this way I sent this list to our heads of departments asking each to add the names of representative employers. As a result there were seventy-two organizations selected for the study. I may add, parenthetically, that our faculty men do not all think alike on the question of the proper length of engineering curricula. We asked for data covering only enterprises being carried on in Southern California.

The next step was to ask questions in such a way that the person addressed would not be influenced in his answer by any opinions of mine. I feel that we were successful in asking the questions in this impartial way since several thought the University of Southern California was about to embark upon the five-year program. The chief engineer of an aircraft manufacturing establishment remarked: "U. S. C.'s new graduate work would have to be along aeronautical lines to interest us."

The letter of transmittal and the text of the questionnaire are as follows:

QUESTIONNAIRE

November 7, 1935

Dear Mr. ————:

Engineering teachers are just now engaged in an animated discussion of the advisability of increasing the engineering curriculum from four to five years. The extra year might be used to give more work of a broadening nature, work of cultural value, or it might be used to increase the fundamental engineering content. Probably a compromise would result and both the cultural and technical content of the course would be increased.

We should be glad to have the opinion of a few representative employers of our graduates concerning the relative usefulness of graduates of the usual four-year courses and those with five or six years of college training. The kinds of engineering to which I refer are: Chemical, Civil, Electrical, General, Mechanical, and Petroleum.

While I am anxious to avoid making any statement which might tend to prejudice you in answering the questions attached, I am suggesting a few considerations relating to the problem. Were all engineering colleges to increase the requirements for a degree to five years we should turn out better educated and better prepared men. On the other hand, this would place an additional burden upon young men seeking an engineering career and would undoubtedly reduce the supply of young engineers. It should be borne in mind, also, that opportunities for study after graduation are steadily increasing.

It seems to me that we should consider the interests of the engineering industries, the young engineers themselves and the public at large, over a long period of time.

If you will be good enough to answer the questions attached (or ask one of your associates to do so) and to make any comments pertinent to the subject you will aid us materially in our discussions. We are particularly anxious to get these data before the end of November.

I thank you in advance for any attention you are able to give this request.

Cordially yours,

PHILIP S. BIEGLER, *Dean,*
College of Engineering

QUESTIONS:

1. Over a period of several years what percentage of young engineers just out of college, employed by your company, are graduates of the four-year courses? ———— What percentage are men with five, six or more years of academic training? ————
2. Considering young engineers in your employ who have had four years of college training and who have been out of college about five years, what percentage of these men do you think would be more valuable in your organization at this time had they spent one or two of these years in college? ————
3. Approximately how many men with engineering training do you have in your organization? ————

REMARKS: ————

We received replies from forty-two of the organizations addressed but some of them felt, for various reasons, that they did not have sufficient data from which to answer the questions. Thirty-three answered the questions with actual estimates, some after considerable study of their records. The estimated number of engineers connected with the organizations or departments which submitted satisfactory replies was 2,683. Thus the study covers a very considerable group of engineers in the vicinity of Los Angeles, and should be of value in our present discussion.

Our survey shows that 81 per cent of these 2,683 are graduates of the four-year engineering courses and 14 per cent are men with five or more years of academic work. The remaining 5 per cent probably are men without degrees. Of course this situation is very greatly influenced by the fact that there has been a plentiful supply of four-year men and a limited supply of men with longer academic training. Thus these results were more or less anticipated.

Of greater importance to the present discussion, however, were the answers to the question regarding the proportion of men whose status would have been improved by more than four years of academic training in the judgment of the executive answering the questionnaire. The average estimate, weighted according to the number of engineers represented in each reply, was that 30 per cent of these engineers would have benefited by more than four

years of college work. This shows an increasing interest in the lengthened engineering curriculum, but is far from indicating that all engineering colleges should adopt the five-year curriculum.

Under "remarks" in the completed questionnaires are indicated some of the reasons why four years for the many and five or more years for the few are satisfactory in many instances. They might be summarized under these headings:

1. Many industries feel that the fundamental engineering training may be satisfactorily given in four years, leaving specialized training to the industries. Men benefit more by a year in field work than a fifth year in college.
2. The additional expense for a fifth year in a large number of cases would be economically unjustified. There are many engineering positions requiring average men only.
3. Opinion was very much divided upon the question of whether the additional material of a fifth year should be humanistic or advanced technical work.
4. In the case of many young men a definite hardship, financially, would result from the increased length of curriculum.

Thus, it may be concluded that industrial leaders in Southern California do not think the engineering colleges should change completely to the five-year curriculum. And, of those men who would benefit by further training, many should undertake advanced engineering and scientific work while others should broaden themselves with a strong program of humanistic studies.

It is therefore my own conclusion that the public is better served, the young engineers treated more fairly, and that we have the support of industry in our present scheme of many four-year curricula and a few but increasing number of five-year colleges. Engineering colleges, within limits dictated by sound scholarship standards, should not be subject to regimentation but should work out their own ideals.

Discussion

Franklin Thomas, Professor of Civil Engineering, California Institute of Technology: Three decades ago the recognition that engineering students needed training in the humanities to fit them better for some of the non technical functions of their work was being displayed in curriculum revision. Courses in English extending through from one to four years were generally introduced as well as elementary economics.

Shortly thereafter developments in the engineering fields required the introduction of new subjects, typical of which, reinforced concrete in Civil Engineering might be cited. Educators confronted with the desirability of liberalizing engineering education and at the same time meeting the necessity of training for changes

in the art and practice felt the added material could only be accommodated by displacing time-proved fixtures in the curriculum or by adding one or more years beyond the standard academic four.

Confusion and some disappointing experience resulted because individual institutions undertook to work out diverse solutions of what was a problem whose aspects were pretty well agreed upon. Following the pattern already established at that time in legal and medical education some universities fixed a requirement of two years of liberal arts study prior to beginning the engineering course. Under this sequence, the B.A. degree would be awarded after four years and the B.S. after six years. In other universities particularly on the Atlantic Coast, the engineering courses for undergraduates were discontinued and transferred wholly to post graduate status subsequent to an arts or science course. The majority of the engineering colleges made adjustments to the new trends without lengthening the course but by making substitutions, reductions and additions. About this time modern languages quite generally disappeared from engineering curricula. There was nothing but what was pedagogically sound in these various plans. However, their diversity introduced competitive elements which after but short experience indicated clearly that only with great sacrifice of attendance could the elongated program be continued. It became apparent that American Youth, or that portion with engineering inclinations, insisted upon motivated education and was not willing to hold those interests in abeyance while he was occupying the intervening two or more years with academic subjects which in his judgment did not have direct technical value to him, especially when many engineering colleges offered what appeared to be immediate access to his idea of practical training as represented by the four year course.

Since there has been no uniform and concerted action among engineering colleges in the direction of extending the standard curriculum beyond four years or of substituting an alternative for the undergraduate technical training, the isolated instances where experimental departures were made have not justified emulation. The psychological and economic factors have constituted almost insuperable obstacles to material change from former procedure.

Meanwhile engineering theory and practice have expanded in scope and application, placing added obligations upon the colleges if they are to prepare their students effectively for new conditions and put them in step with the fields which they are to enter from college. In the last decade, familiarity with such subjects as rigid frames for civil engineers, heat treatment and alloy steels for mechanical engineers and vacuum tubes for electrical engineers has become essential if the output of the colleges is to be useful in

advanced developments in their respective fields. As more general application of analytical theory occurs, the necessity for more thorough preparation in the fundamental sciences of the early college years increases. The larger number of graduate students in recent years probably reflects a recognition of the value of additional time and money invested in advanced training.

Certainly there has never been a time when a broad training with full emphasis upon the humanities was more vital for engineering students than today. Generous allotments of time for mathematics, physics, chemistry, mechanics and their applications are of the greatest importance. The remaining time is available for professional subjects. For each of these three groups of subjects an irreducible minimum considered desirable might be set and still the four years not be adequate.

Considering all the factors just mentioned it would seem that the four years of undergraduate work should be utilized to attain a triple objective of solid foundation, breadth of interest and facility of expression, and professional applications enabling the man completing the course to be definitely useful. The completion of such a curriculum certainly merits the award of a bachelor's degree. In view of the impossibility of the undergraduate period accommodating all the subjects currently useful, additional time on postgraduate status seems to be desirable, and which can be adapted to the needs and abilities of superior individuals. It is distinctly advantageous if a program for a fifth year leading to a master's degree can be provided so as to be well correlated with the undergraduate work. Such a year might well include additional mathematics presented with engineering applications and advanced professional subjects. Not all of those men receiving the bachelor's degree should be encouraged or even permitted to proceed with the advanced work. Dean Biegler's paper presents an opinion that approximately 30 per cent of graduating classes would have benefited by advancing their training as graduate students: that probably is a correct estimate and might prove to be somewhat excessive.

The four year engineering course then has been and is justifying itself by supplying what young men of engineering interests find to be satisfying; also by producing an output immediately useful to the profession generally. It also represents the approximate intellectual ceiling for about 75 per cent of the members of its graduates. Such a course constitutes a satisfactory foundation upon which a limited number of the abler students may continue graduate work and prepare themselves for more highly technical work with resulting advantage to themselves and advancement to the profession.

FIFTY YEARS REVIEW OF ENGINEERING EDUCATION *

By JASPER O. DRAFFIN

Professor, Theoretical and Applied Mechanics, University of Illinois

This is an anniversary occasion, the fiftieth year of the organization of this Society. Anniversaries have a number of purposes: They may honor great men of the past or present; they may furnish an occasion for the older members to recall past experiences; and, perhaps most important for our purpose, they may provide a long back-sight in order to project a straight line ahead of us. We hope here that by an examination and an appraisal of the past we may be able to chart our way into the future for at least a short distance. The desirability of a guide may be illustrated by a story on the professor, a professor of physics who told his class about fifty years ago that there were no more great discoveries to be made in physics. Forgetting the lessons of the past, he said that all of the laws and principles had been discovered and there only remained the refinement of methods and the measurement of constants to a higher degree of precision. This was on the eve of the discovery of X-rays and of radium, discoveries which have entirely changed our conception of the constitution of matter. We may characterize this professor as one lacking in vision and earnestly pray that we may not be like him.

Since we are to consider the changes in engineering education for a period of fifty years, if we are to have a clear picture and to assess properly the educational situation in 1885–1886, we must look back over the road which led up to 1885 and see the background against which our resumé of fifty years must be interpreted. A century ago engineering education in France was highly mathematical and dealt largely with the theory of engineering leaving most of the practical aspect to be acquired in the field and office. This emphasis on the mathematical side was probably due in a large measure to the impetus begun and continued by such leaders of scientific and philosophical thought as Descartes, Newton, Lagrange, D'Alembert, Navier and Poisson. In Great Britain the system of engineering education was almost wholly that of apprenticeship and therefore was mostly of the so-called practical type.

* A paper delivered before the Illinois Society of Engineers, January 31, 1936, on the occasion of the celebration of the fiftieth anniversary of the founding of the Society.

Even here, though, a few men such as Barlow, Tredgold and Hodgkinson were beginning to cultivate engineering from a loftier view, one which, twenty-five years later, was to culminate in the work of Rankine, who more than any other one man formed the mold in which the technical structure of engineering was later to be cast.

In the United States, a century ago, there was neither apprentice system nor highly mathematical education in engineering because the country was too new for either of these systems. Nevertheless the growing industrial plants together with the building of railroads, canals, and bridges, with the machinery to operate them, created a demand for men who could plan and supervise such work. To satisfy this need some of the early statesmen of vision and foresight, men who were in a real sense the early founders and promoters of industry and communication, were resolved to provide the necessary opportunities for such education and training. Fortunately the men who became the heads of the early engineering schools were educators and not practicing engineers, a fact which had an important influence on the curricula and teaching methods employed.

The first professional school of civil engineering in the English-speaking world was established at Troy, N. Y., in 1835 and named Rensselaer after its founder. Following it, six more schools of engineering were established up to 1862, though some of these were but little more than names for years to come. The schools were at Rensselaer, Brown, Union, Dartmouth, Michigan, Harvard and Yale.

The agitation on the part of the public for increased educational facilities, or "For the application of science to the common purposes of life," finally led to the passage of the Morrill Land Grant Act in 1862, a law signed by President Lincoln during some of the darkest days of the Republic and at a time when momentous events were under consideration by Congress. I doubt whether most people fully realize the effect this law had on education in the United States. The Act made financial provision for institutions in which training and instruction should be given in "agriculture and the mechanic arts" as well as in literature and science. Such financial aid had the effect of promoting the engineering arts and at the same time of giving them an equal social standing with the recognized courses in literature and science, the classical education. This recognition, of the equal importance of the old classical and the new agricultural and engineering education, was vouchsafed more fully in the Middle Western states than in the Eastern states, which were already provided with the traditional educational opportunities. Indeed in the newer regions the old and the new types of education grew up side by side and each recognized with-

out question the equality of the other. This appreciation of each other later overflowed into the East to revivify some of the more traditionally minded schools. Even to-day we hear discussions on the recognition of the engineer and on his place in society and we may well ponder what his status would have been if the broader educational recognition accorded to him in this region had not had its leavening influence on other sections of the country.

I have already referred to Rensselaer Polytechnic Institute at Troy. Originally the curriculum required four years, preparatory work for one year and engineering work for three years. But soon the distinction between preparatory and advanced work was dropped and the curriculum became the regular four-year course, a plan which was adopted by later schools. Due to the Morrill Act and the influences which gave it birth, the engineering schools increased from 6 or 7 in 1862 to 70 in 1872, truly a phenomenal growth in a single decade. Not only did the schools increase in numbers but they implanted seeds of new ideas which showed the possibilities of exploration in new and old fields. The growth of these ideas brought into being the Engineering Experiment Stations and similar research organizations.

The items which I have discussed thus far constitute a part of the social, economic and industrial background which had influenced engineering education up to fifty years ago. As we proceed I shall question some of our present educational procedures, not to disparage them but to point out that we still need to keep an open mind.

Since our time is limited, I shall confine my remarks on details of schools to the engineering school of the University of Illinois which may be considered typical of those of the schools of the Middle West. A study of old records shows a few interesting facts which will be cited as side-lights to show the general changes which have taken place in fifty years at the University of Illinois.

In 1885 fraternities were forbidden, the catalogue stating that the existing literary societies served all useful purposes; to-day we have many fraternities. Then the estimated expenses of a student for the school year, exclusive of books and clothing, was $125–220; to-day it is estimated as $425–582. For labor around the University the student was paid 8–10 cents per hour. In the list of students in attendance they were distinguished as *Ladies* and *Gentlemen*. Fifty years ago the number of engineering students might be compassed by the words of the old hymn "There were ninety and nine," while our registration this semester is 1,280, not including those registered in architecture and chemical engineering, which are in separate colleges. The catalogue of 1885 stated that the University Library contained over 15,000 volumes; now our

Engineering Library alone has over 30,000 volumes in it and this is only a part of our engineering books, those used most frequently. Of the periodicals received by the library in 1885 eighteen were engineering and of these one was a French and one was a British magazine; to-day we receive between four and five hundred periodicals, a large number of which are foreign. Surely engineering education has expanded both in numbers of students and in the facilities for study. It is therefore a fair question to ask whether the mental capacity or equipment of the student has expanded and improved along with the new facilities? Or does he merely study more or different subjects with only a smattering knowledge of each?

The engineering curricula contained no electives and no alternate subjects; military science was required but physical education while mentioned does not seem to have been compulsory. Besides architecture, there were three engineering curricula at the University of Illinois, mining, mechanical and civil engineering. All of these had the same basic core that they have to-day, mathematics, drawing, descriptive geometry, mechanics, resistance of materials, chemistry and physics. In addition all students who were candidates for a degree were required to take two years of either French or German as well as Mental Science, Political Economy and Constitutional History; to-day none of these subjects is specifically required except in one curriculum where one year of French or German is specified. Yet our students are not confined to strictly technical study because all of them are required to elect a certain number of non-technical subjects.

Except that the amount of subject matter to be mastered was less, mathematics, mechanics and resistance of materials were taught about as at present; physics and chemistry were given less attention than to-day, particularly chemistry. Skill or training of the hand was emphasized in drawing, shopwork and surveying; machine drawings were finished by shading with lines and water colors. In the shop the mechanical engineering student did work in pattern making, blacksmithing, foundry, bench and machine work in iron; he was taught to produce a complete machine by making the working drawings in the drafting room and building the machine in the shop. He also studied mechanism and prime movers.

For the civil engineering student there was land surveying, railroad surveying, topographical surveying, theory of engineering instruments, geodesy and astronomy to which was added bridges and stone work in the fourth year. He built elaborate models of bridge and roof trusses. A report made in 1887 on an exhibit of student work in mechanical drawing and wood and metal construc-

tion, shown at a meeting of the National Educational Association, emphasized the fact that the work was directed by a rigid method and was done with care, accuracy and finish as well as with honest simplicity.

When we contrast the outline of studies just given with that of the studies of to-day, the difference is striking. Yet the total change in engineering education during fifty years cannot be delineated merely by reciting the names of the subjects studied. The true changes will be found in the changes in the subject matter and in the general spirit and tone which pervades the teaching.

In the past fifty years changes have been made in the direction of expanding somewhat the basic sciences and placing them earlier in the course; the amount of drawing, shopwork and surveying has been reduced; English, the management side of industry and much new and advanced technical subject matter have been added. Some of the new spheres or advances in old spheres of engineering which have been incorporated in engineering education within fifty years are: Steel construction, automotive engineering with the attendant modern highway; concrete and reinforced concrete; electrical enginering; high-speed steel with the accompanying mass production; utilization of the phase rule which is the foundation of many parts of ceramics and metallurgy; water purification and sewage disposal; analysis of stresses in machine parts and secondary stresses in bridges and buildings; the steam turbine and Diesel engine; mechanical refrigeration; scientific management; fluid mechanics; soil mechanics; vibration of machinery; metallography. This brief list suggests something of the tremendous changes which have taken place in the technical content of the curricula and in the scientific and technical aspects of engineering education.

Most of the additions or changes have found their way into the curricula gradually. In 1885 the emphasis in mechanical engineering was on designing and building machinery but soon after that the increased use of the high-speed steam engine and the electric generator began to give power development a larger place in the curriculum of mechanical engineering. The degree to which electricity was taught in 1885 is shown by a statement in the catalogue that "a five-light Weston dynamo has lately been placed in the machine shop and is connected with the physical and chemical laboratories for experimental purposes." The first definite teaching of applied electricity was in 1888 when "Dynamo-Electric Machinery" was taught in mechanical engineering. Electrical engineering as a distinct curriculum was not offered until 1890 when the department of Physics and Electrical Engineering was organized and in 1898 Electrical Engineering became a separate department.

At first much of the teaching in electrical engineering was by physicists who introduced the scientific element to a greater extent than it might otherwise have been done.

So much for the changes in content, what about the method and spirit? One factor which entered early was that of laboratory instruction with its stimulating influence. In a report on engineering education W. E. Wickenden states that "American [engineering] schools have been more adaptive than creative, but in two respects at least they have exercised a conspicuous leadership—the introduction of individual methods of laboratory instruction and the provision of distinctive training in the economic and management phases of engineering."* Though extremely effective when rightly used, it may be questioned whether we have retained to any considerable degree the "individual methods of laboratory instruction" which existed in the beginning. Many educators and engineers feel that, with large numbers of students and crowded sections, some laboratory teaching has become merely treadmill routine with little in it to inspire the student and lead him into that independent thinking which was the warp and woof of the fabric of laboratory instruction in the early days.

The tremendous increase in the subject matter of engineering raises another question, partly of method, that of a specialized versus a broad education. In a searching analysis of the trends of engineering, W. E. Wickenden predicts that "the demand for strictly professional engineering service will diminish in volume but will rise sharply in its qualitatve standards. However the demand for quasi-professional business activity in producing, distributing, and adapting technical goods and services may be expected to increase markedly."† How this sharply differentiated education shall be administered is already a question and we must find the answer. President Wickenden suggests a regrouping at the beginning of the fourth year with an additional one or two years, or what he calls "a second mile," as "highly desirable for a considerable minority, and virtually imperative for a selected few." All this suggests the need for a better or at least a more sympathetic understanding between industry and the engineering college and there are signs that this is being effected.

The picture of the changes in engineering education is not complete until advance work has been included. Yale granted the first advanced degree in engineering, a doctorate, in 1873 to Dubois, and Iowa State College granted the first master's degree in engineering in 1879. Previous to 1890 there were but few ad-

* "A Comparative Study of Engineering Education in the United States and Europe." Bull. No. 16, Investigation of Engineering Education. Society for the Promotion of Engineering Education, 1929, p. 74.

† *Electrical Engineering*, May, 1935, p. 473.

vanced degrees conferred but about 1900 the number began to increase. Even though 40 of the 150 engineering schools were offering graduate work fifteen years ago "such work had not really begun to assume a position of great magnitude in engineering education." * The number of advanced degrees conferred in engineering increased from 178 in 1921–1922 to 1,197 in 1933–1934. Excluding architecture and physics, the Engineering College of the University of Illinois has granted 399 master's, 20 doctor's and 229 professional degrees since it was organized.

Obviously all of the factors affecting engineering education cannot be mentioned but we should not omit the effect of the Engineering Experiment Stations. The first of these was created at the University of Illinois in 1903 and one of the stated objects was "to stimulate and to elevate engineering education." This objective has been attained partly through the stimulus which comes from observing the research work in progress and partly by young men, graduate students, doing such work themselves. It would be a mistake, though, to think that the spirit of investigation is confined to graduate students. Fifty years ago a thesis was required of each candidate for a degree in engineering. This requirement was discontinued about twenty-five years ago because of the large number of students but theses are now elective with some tendency on the part of the faculty to urge the more capable students to choose them.

How has graduate work affected undergraduate work? I have just referred to the stimulus a young man receives when he is surrounded by new and growing problems. Further information is supplied by an investigation conducted in 1935 by a committee of the Society for the Promotion of Engineering Education.† The committee evaluated the effect of graduate on undergraduate work by saying that, "requirements for the bachelor's degree were being decreased; curricula were being simplified; emphasis was shifted from the more advanced technical courses and from purely descriptive work to the more deeply fundamental subjects; less time was devoted to the more mechanical types of work, and the time so released was devoted, in considerable measure, to humanistic studies." One school states that methods of undergraduate teaching have been changed and that "more use is made of the conference and research methods of scholarship. Small research projects have been introduced for seniors." One man stated and a dean emphatically endorsed his view, that "the effect of graduate work has been

* Report of Committee on Graduate Study, JOUR. ENG. EDUC., Dec., 1935, p. 315.

† Report of Committee on Graduate Study, JOUR. OF ENG. EDUC., Dec., 1935.

revolutionary, stimulating the faculty and the interest of the students in their work." Apparently one of the greatest effects of graduate study in an engineering school is the change which it has engendered in the attitude of both the students and the instructors toward their work.

These considerations should lead all of us to attempt to interpret the meaning of some of the changes in fifty years of engineering education. From a situation where the subject matter to be organized and used by the student was relatively small and ample time was allowed for thought and assimilation we come to the present with the vastly larger amount of material which the student is expected to cover, at least superficially. While the student probably memorizes more facts than formerly he has less time for reflection and interpretation. Taken all in all, it is at least open to question whether he has achieved mental growth, whether he has increased his capacity for thinking his way through a given situation, as much as formerly. Besides there is the question of outside or extra-curricular activities. Though many people in industry believe such activities to be of great value, the student must frequently sacrifice grades if he is to engage in activities. I am not decrying our present methods of engineering education but merely trying to show the opposing elements, or what may be opposing elements, for your consideration.

Summarizing the changes which have taken place in the last fifty years, I would say that they have been four in number and are as follows:

(1) Reduction in the descriptive and skills part of the former work and the substitution for it of more of the analytical and mathematical type of study.

(2) Increased emphasis on the elementary part of the basic sciences on which engineering rests.

(3) The introduction of a large number of new branches, phases or types of subject matter and the consequent increase in the amount of material which the student is expected to master.

(4) The growth of graduate study which has not only provided advanced engineering education for a few students but which has enriched and stimulated the entire undergraduate curricula.

THE INFLUENCE OF THE EDUCATION DEPARTMENTS ON ENGINEERING EDUCATION

By FRANKLIN O. ROSE

Instructor in Engineering and Mathematics, Modesto Junior College

There has been, in the past, considerable informal discussion of the subject among college instructors and faint rumblings of protest against the activities of the education departments of the colleges and universities have recently found their way into print; for example, the remarks by Dean Anderson and President Rogers in the February, 1934, number of our JOURNAL. I have attended a great many meetings and conferences where we have aired our grievances, real or fancied, and felt sorry for ourselves, but have never made any effort to remedy a situation by taking up the matter discussed with the proper authorities. It is my sincere hope that this paper will provoke a discussion which, if it be deemed advisable by the Junior College Committee, will result in a report to the Society, asking for a careful investigation and appropriate action.

The first item I should like to bring to your attention is that of educational requirements for junior college engineering instructors, the subject of the suggested title of this paper. I am not familiar with the laws in the various other states but, in California, and I presume elsewhere, in order to secure a teaching credential for junior college work, it is necessary to have at least ten semester-units of education. It is obvious that this requirement greatly reduces the number of desirable engineering teachers available for junior college positions, as few engineers, qualified by professional experience for teaching, care to spend the time or money on the irrelevant work of the required education courses. I speak of the irrelevancy of the work from personal experience.

If junior colleges are to become more and more institutions of the terminal or completion type, it is even more important than in the undergraduate work of the senior colleges that the teaching staffs in engineering be made up of men of considerable practical experience, in addition to their technical training. This point was admirably brought out by Professor Raymond E. Davis, of the University of California, in a paper on junior college work presented at the Corvallis, Oregon, meeting of the Society in 1932.

Of course, the answer of educators to this objection would be

that the mere knowledge of subjects to be taught, acquired through training and experience, would not be a sufficient qualification for a teacher. I would vigorously question such an assertion. Teaching ability, with some people, follows the acquisition of knowledge, and, with others, it does not. Exposure of the latter to a specified number of education courses will not produce it, and the lack of it could easily be discovered during a probationary year of junior college teaching, provided that the junior college administration would make any investigation in that direction.

I should like to see a committee instructed by the Society to investigate this matter carefully and to decide whether any recommendation could be made to the Society covering action which might relieve candidates for junior college engineering positions of the aforementioned requirements. I know of no body better qualified to judge the merits of this case than the Society for the Promotion of Engineering Education. Action of this kind would also show very clearly where this Society stands on the question of the possible upward extension of this educational requirement to include teachers in the senior institutions.

The foregoing constitutes but one of the influences of the education departments on engineering education. Another influence, and one far more wide-spreading in its application, in that it applies with equal force to fields other than junior college engineering instruction, is that of the policies and ideas advocated by educators and spread perforce among such multitudes of embryo teachers. It must be understood that the value of all, or even a great part of the work of the education departments is not being questioned. The value of any of it, however, depends entirely upon its place and manner of application, but right here the educational schemes may be likened to the mathematical formulas and tables used in engineering work. The latter are useful if they are correctly derived or computed and if they are intelligently handled. Unfortunately, however, the people who enroll in the education courses are, for the most part, quite immature, and rather inexperienced with the world and its people. Such persons are quite apt to take the ideas they have heard and use them in not exactly the most intelligent manner; in fact, they often do. The same might be said of a great many of the occupants of public school administrative positions, who speak with hushed voices when they talk of educational theories.

I am thinking particularly of the emphasis placed by educators upon the importance of teaching technique, at the expense of subject matter. If I had ever heard a member of an education department admit the importance of knowledge of subject matter, or of one who had ever suggested this importance to his students, I

would not feel so strongly on this question. This emphasis is well illustrated by the case of a man in a prominent western university who was just about to receive his degree of doctor of education and to embark upon a teaching career. He called upon one of the members of the engineering faculty, explained that he was going to accept a position in the fall where he would teach surveying and asked if he would be willing to just outline the subject for him. The engineering instructor asked him if he had taken an engineering course, had studied surveying, or had worked at it, to which he replied in the negative but mentioned the degree which was about to be conferred upon him and stated that he knew all about teaching methods. The engineer had to admit his inability to be of much assistance to him, but the candidate, as far as I know, secured the position.

Another engineer, in the course of a discussion with a member of an education department, stated his opinion that it would be beneficial if all prospective teachers would, after completing their academic and education courses, go out from college halls for a year or two, into some other kind of occupation, so as to learn something about the world their future pupils would enter. He was met with the reply that this would never do as, in the interval, they would completely forget what they had been taught about teaching methods. Perhaps it would be as well.

In one high school that I know of, the principal had become imbued with the importance of "training for leadership," as expounded at some summer session which he had attended. The idea was carried to the extreme of having the high school classes organized into committees, with rotating student officers and the teacher effacing himself as much as possible. The amount of mathematics, say, which could be taught under this system by ever so good a teacher of mathematics must be evident to any thinking person, and yet that school was supposed to be preparing students for all departments of the university, including engineering. Training for leadership is of questionable value, unless such training teaches the student where as well as how to lead.

Junior college instructors in California, along with all other public school teachers, attend annual teachers' institutes. At all such meetings which I have attended, the so-called inspirational addresses have been delivered by professional educators. This savors of inbreeding. The value of talks to the teachers by eminent persons in the fields of science, literature, law or the arts seems to have been entirely overlooked. This indicates again where the emphasis lies.

The foregoing instances, and many more could be given, are cited with the sole object of emphasizing a serious existing situa-

tion by giving specific details. In all probability, what has been said does not indicate the aims of the great majority of educators. It is, nevertheless, indicative of the results obtained, to a great extent, as far as public school teaching is concerned. At the risk of being likened to poor mechanics, who blame their tools, I feel that we should call attention to this emphasis in education as one possible reason for the apparent lack of preparation exhibited by so many college freshmen. This lack is noticeable in the senior as well as in the junior colleges, because, although entrance to the former is dependent upon having certain recommended grades from high school, such grades are not always an indication of the amount of preparation in subject matter which the student has had. Teaching technique is undoubtedly of paramount importance in the elementary grades, but when its importance is stressed, as it is, at the expense of subject matter in the higher preparatory grades, it becomes downright detrimental. This is particularly true in the case of preparation for scientific or technical courses. It would thus appear to be a matter of interest to the faculties of both junior and senior colleges.

We all know that members of our Society welcome advice and criticism of our methods from members of the engineering profession, based upon the performance in the profession of our graduates. Is it not possible that this Society, and other like societies interested in the promotion of education, are eminently qualified to offer similar advice to the educators, based upon our observations of the results of their efforts? If this be so, I should like to see it done. So far, they seem to have been untrammelled by such advice.

It may be that I am barking up the wrong tree in what I have said. However, I know that I have reduced to writing the barks of a great many of my colleagues in engineering education, and discussion of the points raised should be of value.

TEACHING THE COURSE IN TECHNICAL WRITING

By CARL NAETHER

Associate Professor of English, University of Southern California

The emphasis which many colleges and universities place on courses in so-called technical writing is most encouraging. It meets with hearty response and coöperation from professional engineers and firms in the engineering and manufacturing field, in whose employ the majority of technical students find themselves after graduation, and whose more or less insistent and persistent demands for college-trained apprentices able to speak and to write English correctly and forcefully, has perhaps resulted in schools offering would-be engineers courses in writing somewhat more practical and fully as "cultural" as the general and usually compulsory beginning courses in composition, dreaded often as much by teacher as by those taught. For it can hardly be gainsaid that work in freshman composition as it is offered generally in colleges and universities is, owing to a decided lack of close coöperation between secondary schools and colleges, merely designed to re-teach the student thoroughly those simple principles of rhetoric which the high-schoolma'am, too busy or too bored with her tasks, has apparently failed to appreciate and emphasize.

Since students just entering from high school regard the traditional and required course in composition not merely with blatant indifference but often with ingenuous skepticism of its intrinsic worth in the scheme of after-college life, it behooves the teacher of technical students to imbue them with the common-sense importance of English as it should be spoken and written by men in the engineering and related professions. In other words, in order to induce young high school graduates to strive intelligently and strenuously for mastery in spoken and written language expression, there needs must be shown them in most instances that such accomplishment is not just a school requirement, but a requirement of the stern workaday world, in which the student hopes to occupy a worthy place after he leaves college or university.

Fortunately the writer of this article has served an apprenticeship in the engineering and the business office extending over a period of years sufficient to help him realize once and for all the very direct and often dire need which nearly every man in any way connected with the practice of engineering or business has for

the use of good English. And comparatively recently, when he in collaboration with a former colleague prepared the manuscript for a work on English for Engineers, he took advantage of the opportunity to discover anew and to scrutinize afresh this same need, devoting considerable time in the offices of professional engineers to a study of the particular forms of rhetoric appearing in engineers' writing and speaking. Owing to this more or less recent, intimate, and continued contact with the engineer's work, his duties and ideals, the writer has come to respect the course in technical writing as an eminently useful piece of work to be handled with forethought and with enthusiasm, a course combining worth-while phases of liberal education with equally worth-while phases of professional education.

The content of the course in technical writing depends on a number of widely diverse factors, such as the type of college or university in which it is offered and the specific reasons for offering it in the first place; the curriculum year in which it appears; the length of time it occupies; the number and class (as regards mental ability) of students to whom it is offered; the experience and ability of the instructor, and his sympathy with the technical man's point of view and problems; the freedom which the instructor is given in moulding his work to the needs of his students and the times; and perhaps the problems of the technical profession in spoken and written English in the state or region in which the college or university is located.

Assuming that the course is begun in the freshman year, as is customary almost everywhere, and that the students have been placed in it on the basis of some really comprehensive written test in English, thus having in common a uniform and preferably high degree of ability in its use, the instructor will in the first few weeks of the term seek through every available means to ascertain as quickly and accurately as he can the extent of the student's efficiency and deficiency in his writing, and shape the presentation of his subject accordingly. Thus it is common practice among many teachers of freshman English to inaugurate the initial semester's work by a rapid review of the fundamental principles of grammar, and of sentence and paragraph construction with a view to discover the extent of the student's training in these important matters. Indeed, in cases where the freshman's high school training in English shows serious weaknesses, the entire first semester of the freshman year is given over to a review of the laws governing the formulation of thoughts into effective, readable sentences and paragraphs. The subject matter for such work may be taken from the usual handbook, supplemented by materials obtained from engineering periodicals and books so as to stimulate and steady the

student's practical interest in the work. It is good practice to let the student himself search technical publications for exercise material to be used in class, since it will acquaint him with the nature and type of writing which he himself may be required to do later.

The review of high school grammar and rhetoric is best followed by a presentation of the principles underlying the effective writing of expository, argumentative, descriptive, and narrative compositions—which, in fact, covers the work of the first year. Each type of discourse is treated in its proper turn from a broad practical standpoint with a view to giving the technical student an illuminating and useful preview of the entire field of rhetoric so that he will leave the course and the college with a mind open to the usefulness of all types.

Since most engineers employ in their reports, letters, speeches, magazine articles, and other forms of written expression, exposition more than any other type of rhetoric, and since the average freshman has written expositions in high school, it is logical and expedient to reserve the most prominent place in the scheme of the first year's work for a detailed presentation of and intensive practice in the principles of expository writing, emphasizing the varied and almost daily practical worth of this type of discourse to the technical student—the apprentice engineer. Whatever exercise materials are utilized should preferably be drawn from the writings of technical men, thus constantly impressing the learner with the pertinent fact that the study of written English is after all a thoroughly worth-while and practical piece of work, proficiency in performing which should concern him fully as much as proficiency in mathematics. To avoid making the course at all narrow, half of the longer and more formal papers required each or every other week are ordinarily based on more or less technical topics; the other half on topics of general interest.

During the second semester each student bases half of the called-for compositions on carefully planned field trips which he takes under the supervision of an engineering professor. He hands the paper for correction first to his English teacher, who then turns it over to the engineering colleague for criticism of the more technical aspects of the student's work, which is thus awarded two separate grades. Experience has shown this method of coöperation between the Engineering and the English Departments to have a very vitalizing effect on the student's work, since he knows that he has to please two different departments. The other half of the required compositions may deal with subjects of interest to any intelligent young man, being often based on class discussions of political, sociological, economic, or religious questions of the hour and day. Whereas the topics for the technical papers are

assigned by the engineering department, those for the other papers are merely suggested by the English Department, each student being purposely permitted a certain freedom of choice.

The work of the second semester consists of a study of argumentative, descriptive, and narrative forms of writing. Since the practising engineer is many times called upon to marshal cogent facts and substantial reasons in defense of the stand he takes in a given public or professional matter, the engineer-to-be should certainly familiarize himself with those phases of argumentative discourse which every intelligent man and citizen should know how best to employ at opportune times. Moreover, since classes in technical writing are as a rule made up of male students only, and since usually the intelligence level of the technical student is much higher than that of, shall I say, the common run of liberal arts students, it is not difficult to incite his interest in pertinent argumentative questions with a view to reasoning them out clearly and comprehensively, though not necessarily conclusively. Moreover, the treatment of reason and argument, with detailed emphasis upon fallacies, affords the teacher of technical composition a splendid opportunity for giving students exercise in oral English, since it is a comparatively easy matter to let a group of young men take definite sides on an issue that is of lively and perhaps immediate concern to them all.

Of course, it is always good practice to have certain students form what may constitute a tentative debating team, the personnel of which may be changed frequently so as to afford as many members of the class as possible practice in spoken English. That such practice, whether it be in the form of debating, reading, or reporting, should constitute an integral part of all courses in first-year composition, most teachers of English are fortunately agreed, since good speaking and good writing should, even if they often do not, go hand in hand. It may be mentioned at this point that the Forum Magazine has frequently been used by the writer as a potent and prolific source of materials for argumentative oral and written class discourse.

Of the two remaining types of writing—description and narration—somewhat greater stress is placed on the treatment of description since the student has in his technical courses frequent occasion to use it. On the engineering field trips undertaken regularly every two weeks during the second semester, the participants are expected to observe accurately, distinctly, logically, and completely, and to make precise and concise written notes. The subsequent reports of what they have thus seen, heard, and felt, are usually terse technical descriptions of various engineering and manufacturing plants, their human and material equipment, and

their operation. To be able to judge the quality and the extent of written reports on field trips, the instructor in English finds it expedient frequently to accompany his students on their journeys of investigation. Because there are present in classes in technical writing often students other than engineers, such as chemists and architects, who do not make these field trips, special assignments in harmony with the professional interests of such students are provided. As a matter of fact, after teaching so-called applied English for a good many years, the writer has found that most technical students *want* to write on certain subjects closely allied with their professional work in school, so that they seldom lack timely trenchant topics.

The fact that most technical men have comparatively little occasion to write narratives in their daily routine, and also the fact that most schools provide special courses in advanced narrative writing, precludes the need of dwelling at length on this subject in the first-year course in technical writing. Furthermore, since it is customary for the student of technical writing to read, and to review in writing, during the second semester, at least one novel of average length, in addition to other types of books, he in this wise studies and reports at some length on the application of the principles of narrative discourse.

This, in brief, is a survey of the principal subjects treated in a beginners' course in technical writing. It differs from the general course in that the members of the class are continually made to visualize the application of their writing to their chosen future activity in life. Such visualization frequently results in the student's manifesting keener interest in his work, in his striving more determinedly and more intelligently to attain a certain mastery at least of fundamentals.

Without exaggeration it may be said that the practical and professional point of view from which the work in technical writing is offered has a decided tendency to so unify and cement the various often loose and hazy ideas and aims of the individual members of the class as to reduce these aims to the single central problem of learning to express one's thoughts in a manner at once appropriate to the occasion and to the reader, whatever these may be. Those of my readers who have taught both, courses in general and courses in technical composition over a period of years, will no doubt agree with me that the atmosphere in the latter is almost always one of eager enthusiasm and serious studiousness, certainly conducive to steady, sturdy, and well-disciplined effort, and differing in these respects markedly from the conventional attitude of dislike so freely and frankly shown to courses in general freshman English.

Though the practical point of view is stressed during the course in technical writing, the student is certainly not taught that technical writing is a type of written discourse distinct from other types, or that the rules underlying the writing usually done by engineer or architect differ from those applied to so-called literary writing. Rather he is given to understand that acceptable technical and acceptable literary compositions have in common qualities of clearness, correctness, force, beauty, and, above all, individuality or character. Whatever other qualities good literary writing may have to have, the five just mentioned, being the essential attributes of impressive technical writing, are brought to the student's attention as often, as variedly, and as forcefully as possible, to the neglect or exclusion of all others.

WHAT A YOUNGSTER THINKS OF ENGINEERING EDUCATION

By J. R. CONNELLY

Assistant Professor of Mechanical Engineering, Lehigh University

Six years ago my experience as an engineering teacher began. Since that time I have taught my classes, taken graduate work in Education, attended faculty meetings, professional and S. P. E. E. annual meetings. In the majority of cases I have kept my ears open and my mouth shut at these meetings, not always from choice.

By this time I have formed definite opinions on things I know something about and like all others on some things I don't know so much about.

Other young fellows like myself have heard a lot about what the older members of the S. P. E. E. are thinking about Engineering Education, but who knows what the younger members are thinking? In many respects isn't the latter more important to the future of the S. P. E. E. and Engineering Education?

The following brief sketch does not attempt to solve all the problems of Engineering Education but it does reveal my personal Philosophy of Education.

Boys come to an engineering school primarily because they or their families believe that the boys will grow up to be most happy in the profession of Engineering. These boys and their parents also evidently believe that in the main an engineering education is the best preparation for engineering work.

To state the matter simply, success in engineering practice is the ultimate aim of engineering education.

Those men engaged in engineering work fall roughly into two classes. The difference between them is aptly illustrated in the medical field by the physician and the laboratory technician. The laboratory technician is skilled in the repeated doing of various tests but is not trained to interpret the results on a case. The physician on the other hand may not be as skilled in the tests as the technician but the physician is trained to take the results of the tests and on them base his diagnosis and treatment. So too in engineering we have those skilled in doing things that involve little interpretation and judgment. We have others who must interpret the results obtained by others and apply them to new

problems. To be successful one must advance the art not simply copy the works of others.

It is essential that this difference be recognized in planning a curriculum, course of study or single exercise. The student engineer is some day going to interpret the findings of technicians in the light of his familiarity with the basic facts of the physical world. Before he is capable of wise interpretation he must have a rich and varied experience with physical fact, human behavior and personal decision.

Too often we assume that a rich and varied experience is the end in itself rather than a means to an end. A rich and varied experience of physical fact, human behavior and personal decision is useful only insofar as it is integrated by the mind of the one having the experience. It is an old familiar proverb, "Get knowledge, but with all thy getting get understanding" ('or heart' in modern translation). In other words knowledge should produce a change in the individual so that all his being is colored by his experience.

All education on the college level should have as its primary aim the development in the student of a self-sustaining habit of growth in thought processes. It is an attitude, it cannot be read in books although books contribute. The predisposition to integrate one's experiences should be the product of an engineering education.

The wise budgeting of student study would place greatest emphasis on the development of this desired attitude and then if space and time permit fill in with the beginnings of professional work and background. However, if we wish to teach men to think we must supply tools, motive and materials or (1) methods of thought, (2) a reason for thinking and (3) something to think about.

In the past engineering schools have relied on physical fact almost entirely, lately some are beginning to add human behavior. Personal decision is still left to chance and extra curricular activities. In addition it is easy for a teacher to fall into the habit of teaching physical fact as an end in itself rather than as part of the way to understanding. One reason for this is that knowledge is much easier to test for than understanding.

This blind faith in the virtue of physical fact alone, leads whole colleges away from their primary objective in an effort to keep up with all the special studies of modern science. It is an educational Will-O-The-Wisp. Just as one new study is half placed in the catalogue another pops up.

Some educators, realizing that technical knowledge alone does not achieve the ends of an engineering education have suggested

"Liberalizing the curriculum" as a panacea. When boiled down to its actual effects this term usually means adding a few courses in the Arts and other colleges. In practically all cases these courses are *technical courses for the Arts students.* Evidently these educators believe that if a lot of their own technical knowledge has not developed understanding in student engineers then a little of someone else's technical knowledge will do the trick. (Parenthetically it might be noted that arts students rarely take engineering courses for their "liberalizing effect.")

There is one sure cure for over-emphasis on technical knowledge and crowded curricula. That cure consists in directing once more our efforts and aiming all our work at the primary object of a college education, namely, the predisposition to integrate one's experiences into a changed attitude or understanding.

Not only is what we teach important, it is equally important where we place emphasis when we teach it.

THE PLACE OF PHOTOELASTICITY IN ENGINEERING INSTRUCTION *

By MAX M. FROCHT, Ph.D.

Associate Professor of Mechanics, Carnegie Institute of Technology

The purposes of engineering education are manifold. One of the basic purposes of engineering education is to develop competent designers of structures and machines. In the present art of engineering education and practice, the theoretical principles of designing are associated with some aspect of the stresses produced in the members of the structure or machine by the external loads. This accounts for the universal practice of according a prominent place to the science of engineering mechanics, and, especially to the science of strength of materials, in all engineering curricula.

Photoelasticity is an experimental method of stress analysis with certain advantages over both ordinary or elementary engineering methods as well as over advanced mathematical methods which recommend it to an outstanding place in both graduate and advanced undergraduate engineering studies. It is the purpose of this paper to show the merits of this method of stress analysis and its major engineering applications, as well as to point out in terms of engineering mechanics the degree of its reliability.

In the conventional treatments of stress analysis there are several basic assumptions:

First, that axial loads produce uniform stress distribution;
Second, that longitudinal stresses in bending follow a linear law;
Third, that the horizontal and vertical shear stresses in beams follow a parabolic law of distribution.

These assumptions are true in special cases only. Generally they are false, and even as first approximations they yield misleading results.

Consider a column resting on a flat foundation and subjected to a concentrated axial load P, Fig. 1. Assume further that the foundation and the bottom surface of the column are both properly machined, having plane surfaces normal to the axis of the column

* Presented at the Annual Meeting of the S. P. E. E., Cornell University, June 19–21, 1934.

and load. Under such conditions the stress distribution, according to the elementary engineering theory, is supposed to be uniform, and the stress S is given by the well-known equation

$$S = \frac{P}{A},$$

in which A is the cross sectional area. It can be shown, however, that this conclusion is not true. The actual stress distribution, instead of being uniform, contains marked stress concentrations, the stresses approaching infinity at the edges, as shown in Fig. 1.*

Consider further a normal section A–A across the column in Fig. 1 and neglect all bending stresses, as would be the case in very

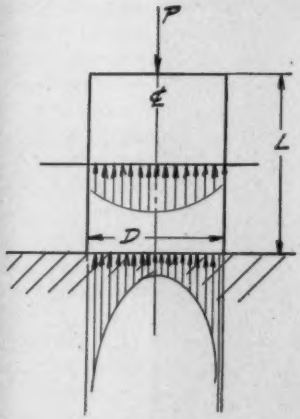


FIG. 1.

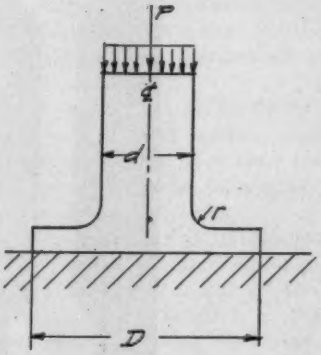


FIG. 2.

short columns or struts. It is usually assumed that in such struts the distribution is uniform. This, again, is not always the case. In order to have uniform distribution the ratio of the length L to the width D must be greater than 2.3 approximately.† If the ratio be less than that, the distribution is non-uniform, the peak being at the center. In extremely short struts the stresses not only vary in

* See "Distribution of Pressure Concentrated on a Small Surface," by Michael A. Sadowsky, *Transactions A. S. M. E.*, 1932. Also "Kinematography in Photoelasticity," by M. M. Frocht, *Transactions A. S. M. E.*, 1932.

† These results are from unpublished work by the writer.

magnitude, but also in sign, there being developed tensile stresses on the vertical edges of the strut.*

Consider next the problem of the column and footing, as shown in Fig. 2, in which the load is distributed over a larger area of the base. It is interesting to observe that if r and d be kept constant the column itself would contain smaller stresses at the fillets if D be reduced, as it has recently been shown that the factor of stress concentration is a function of D.†

FIG. 3. Tensile fractures of bakelite models (see also Fig. 9).

The writer has recently had occasion to investigate the tensile strength of bakelite. Several models were prepared, having the shape shown in Fig. 3. In the first model the ratio of the transverse areas of the head to the shank was 11/16 : 5/16 or 2.2, the intention being to cause fracture through the shank. This, however, was not the result. The models broke through the head.

* See "Compression of Rectangular Blocks," by Dr. J. N. Goodier, *Transactions A. S. M. E.*, 1932. See also Master's Thesis in Mechanics by S. Jory, Carnegie Institute of Technology, 1935.

† See "Some New Aspects of Stress Concentrations," by M. M. Frocht, read at the convention of the American Association for the Advancement of Science, Dec. 1935, at Pittsburgh, Pa.

Several models were then prepared in which the pin holes were successively reduced from 5/16″ to 1/4″, 3/16″, and 1/8″ diameter, thereby increasing the ratio of the areas of head to shank. The results, however, were the same as in the first case. The models consistently broke through the head. To increase the ratio still further, a model was prepared in which the shank was 1/4″ wide and the pin hole in the head 1/4″ in diameter, giving a ratio of area of head to that of the shank of 3. But this proved of no help. The model again broke through the head.

The elementary engineering theory of strength of materials does not and cannot explain these fractures, because it is a theory of average stresses rather than of exact stress distributions. From the point of view of the elementary theory, these fractures represent so many puzzles. The reason why the models broke at the head and not through the shank is found in the different type of stress distribution existing at these sections under the same axial loads. In the shank the stresses were uniform, whereas in the heads the stresses were non-uniform, there being marked stress concentrations at the holes.

The cases just cited bear upon the basic assumptions in elementary strength of materials and prove that axial loads do not necessarily produce uniform distribution of stress, also that the dimensions of an element do not always constitute a satisfactory criterion of its strength.

We turn our attention now to the engineering beam theory. Here we find that the assumption of linear distribution of longitudinal stresses gives a fair approximation to the actual stresses only in cases where there are no sharp discontinuities in the boundary. If a beam contains a groove or a notch on the boundary, the linear distribution is radically altered. The same is true in regions around holes in the vicinity of the boundary. Barring such discontinuities or holes, the flexure formula gives quite satisfactory results for engineering purposes. This, however, is not the case with the shear formula. The assumption of parabolic distribution of vertical or horizontal shear is decidedly in error. The writer has recently investigated * such shear distributions in a number of simply supported centrally loaded beams having ratios of span to depth of 3, 4, 5, and 6, and some of the results are shown in Fig. 4. From these curves it will be seen that the maximum vertical shears are much greater than the maximum from the parabolic formula, and that this maximum does not occur at the neutral axis, but close to the point of application of the load. This fact

* See "A Photoelastic Investigation of Stresses and Isotropic Points in Centrally Loaded Simple Beams," by M. M. Frocht, 4th International Congress of Applied Mechanics, Cambridge, England, July, 1934.

may have special significance in steel-reinforced concrete beams in that it would indicate the existence of much greater shear stresses than have been assumed to exist. It would also show that the flanges of I-beams carry more of the total shear than is usually assumed. It is interesting to note that the maximum shear stress found in these investigations was at least four times as great as the maximum given by the parabolic equation.*

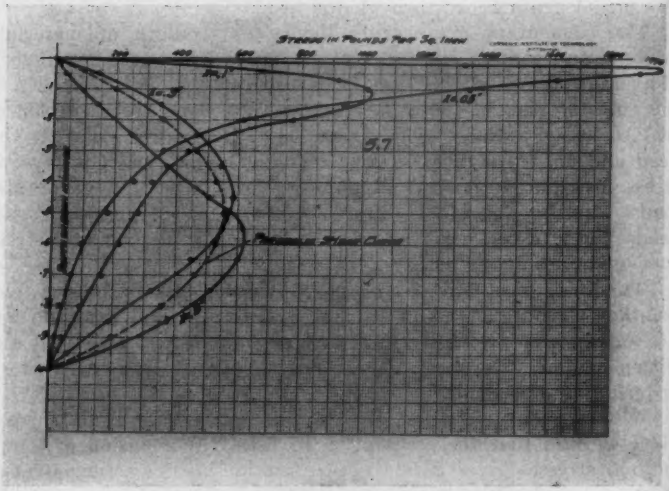


FIG. 4.

The writer has dwelt upon the shortcomings of the elementary engineering theory not in the spirit of adverse criticism, but only because he wishes to point out the great service which the photoelastic method of stress analysis can render to the teacher of mechanics, machine design and structures.

It is true that some of the shortcomings of the elementary theory can be corrected by the mathematical theory of elasticity. This theory is, however, not as effective a tool as is the photoelastic method, the technique of which is steadily improving.

In the present paper we wish to emphasize not the photoelastic theory, nor its technique or procedure, but rather the general nature of the data directly or indirectly obtainable from photoelasticity, its major applications, and its reliability.

First and foremost, the polariscope furnishes stress-patterns of two-dimensional stress systems from which the difference of the

* *Loc. cit.*, 6.

principal stresses at each point of the system can be determined. This phase of the work has now been perfected to a point of extreme accuracy. Fig. 5 shows a typical stress-pattern obtained photoelastically.

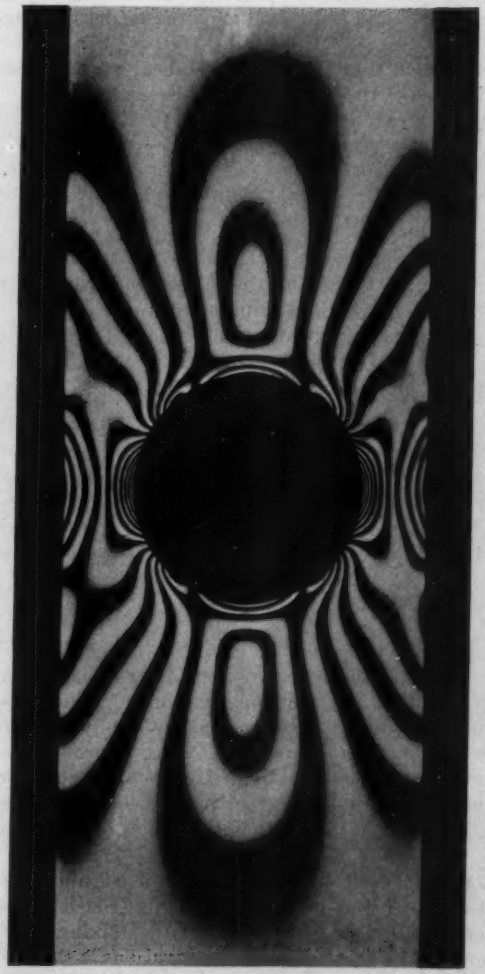


FIG. 5. Photoelastic stress-pattern of a circular hole in a field of pure tension.

The interpretation of these patterns is based upon an experimental fact which can be expressed by the equation

$$p - q = 2.n.F, \tag{1}$$

in which p and q denote the principal stresses at a point, n the fringe order, and F the fringe value of the model in terms of shear stress.

It is well known that the maximum shear τ at any point equals half the difference of the principal stresses at that point. Equation (1) can thus be written as

$$\tau = nF \tag{2}$$

from which we deduce two very important principles to guide us in interpreting stress-patterns:

First, that for n constant τ is constant, that means that an isochromatic or fringe in the stress pattern is the locus of points of constant maximum shear;

Second, that τ is directly proportional to the fringe order n, since F is a constant for a given model.

There follows a very important immediate application of these patterns to the solution of stress problems. Consider for example an element P on a free-boundary. Since by assumption the boundary is free from shear, the faces of such an element are principal planes, and the stresses acting upon it reduce to either a pure tension or a pure compression tangent to the boundary. The maximum shear τ at such boundary points is therefore given by

$$\tau = \frac{p}{2}.$$

But τ is known photoelastically. It follows that p can be computed. Herein lies a major application of photoelasticity. *In addition to providing a means for the determination of the maximum shear stress at any point in a body, it provides an effective tool for the immediate evaluation of free boundary stresses.* Photoelasticity has thus become the tool par excellence for the study of stress-concentration at fillets, notches, holes, or other discontinuities.

One does not need to dwell upon the significance of stress-concentrations before a body such as this, consisting of teachers of engineering subjects. Fig. 6 shows a striking case of failure of a machine part due to stress concentrations.* There is a growing belief that failures of most machines in service are due to

* Fig. 6 by courtesy of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

stress-concentrations. This is especially true where the machine or structure is subjected to fatigue or vibration.

Another application of the photoelastic method to free-boundary stresses is found in the study of maximum tensions in beams. Here again the stresses can be computed directly from the stress-pattern.

In addition to yielding stress-patterns, the polariscope also furnishes directly the so-called isoclinics, which enable us to

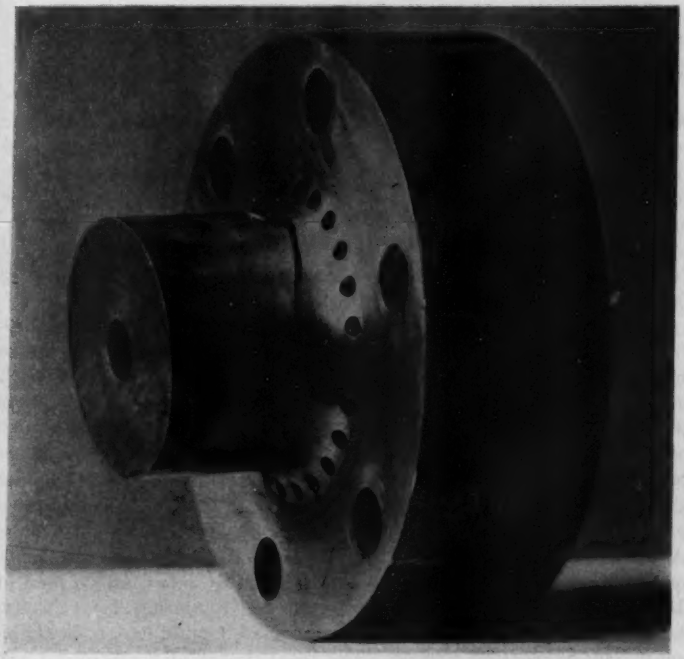


FIG. 6.

determine the direction of the principal stresses at any point of the stressed body or model. This additional data provides another application of the photoelastic method to engineering problems.

Let us recall that the shear stress τ at a point across a section making an angle θ with a principal stress at that point is given by the expression

$$\tau = \frac{p - q}{2} \operatorname{Sin} 2\theta,$$

in which p and q are as before principal stresses. It thus becomes possible to determine shear distributions across any section from a knowledge of the stress-pattern and the corresponding isoclinics.

This is especially useful in the study of vertical or horizontal shear distributions in beams. Thus the curves shown in Fig. 4 have been determined by the photoelastic method.

An important classroom application of the photoelastic method is provided by the interesting and instructive stress patterns. They can be used to demonstrate, by means of slides, moving pictures, or the direct use of the polariscope, many basic ideas of stress distributions, thus adding a visual tool of classroom instruction to the present methods.

In addition to the applications already mentioned, which are all based upon direct data from the polariscope, the photoelastic results may be combined with values of the sums of the principal stresses obtained in one of a number of ways, and from these the complete system of principal stresses can be determined. The methods for determining the sums of the principal stresses are complicated and time consuming. Considerable progress has recently been made also in this branch of stress analysis.* It is beyond the scope of this paper to discuss these in detail.

Thus far we have concerned ourselves with some basic assumptions in engineering mechanics and their shortcomings; we have summarized the fundamental data from photoelasticity and pointed out the applications of the photoelastic method to engineering problems. There remains the question of the degree of reliability of the photoelastic method, as well as the question of the relation between the results from photoelastic materials, such as bakelite and celluloid, to structural materials. Fig. 4 shows a comparison of actual shears in beams and photoelastically determined shears. A bakelite beam $6.25'' \times 1'' \times .203''$ was supported near the ends on small steel rollers to give a clear span of 6 inches, and a load of 130.6 pounds was applied at the center. The actual shear in this beam is, of course, constant, and equals 65.3 pounds. It is represented by curve 1 of Fig. 7. The total shears at 30 different sections in one-half of the span were determined also photoelastically, using for this purpose the curves shown in Fig. 4. The photoelastic values are shown by circular dots. The error of the average shear of all the 30 sections is 3.2 per cent. The largest errors occur in the interval between $x = .8''$ and $x = 1\frac{1}{2}''$, in which it amounts

* See paper by H. Neuber, Royal Society Proceedings, 1933. Also "On the Application of Interference Fringes to Stress Analysis," by M. M. Frocht, *Journal of the Franklin Institute*, June, 1933. Also "Membrane Analogy Supplementing Photoelasticity," by J. G. McGivern and H. L. Supper, *Transactions A. S. M. E.*, 1933, and "Studies in Photoelastic Stress Determination," by E. E. Weibel, *Transactions A. S. M. E.*, 1933.

to 7.2 per cent. Inspection of the stress-pattern not shown in this paper shows it to consist of 3 separate photographs rather imperfectly matched, to give one unit. The larger errors are probably due to this cause. Attention is also directed to the fact that these

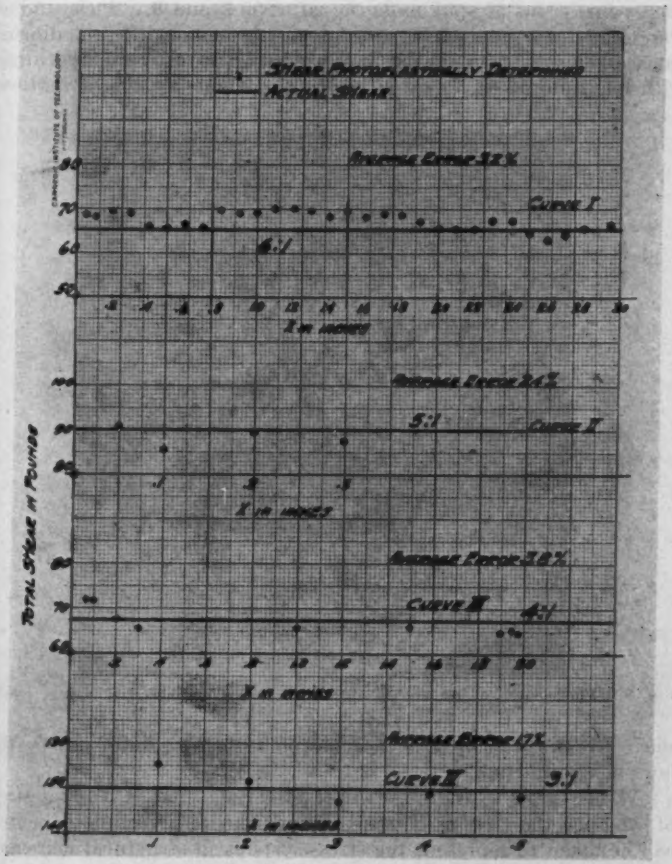


FIG. 7. Results showing the reliability of the photoelastic method.

errors are all positive at the central sections, and that they diminish in size and become negative at sections close to the reactions. This would indicate a possible small error in the load of perhaps 1 per cent or 2 per cent. Thus, if the load was 132 pounds instead

of the estimated 130.6 pounds, the errors would become equalized and smaller throughout the beam. The applied load was determined with considerable accuracy. However, an error of 1 per cent or 2 per cent is well within the experimental limits. Curves II, III, and IV show similar comparisons for the total vertical shears for beams of span-to-depth ratios 5, 4, and 3. Such studies were made at a total of 56 sections of 5 beams of different dimensions and loads. On the basis of extensive investigations dealing with longitudinal stresses and bending moments as well as vertical

FIG. 8. Photograph of an etched steel disk under vertical diametrical loads.

shear stresses we conclude that the photoelastic results satisfy the laws of equilibrium.*

With regard to the question of materials, that is, the question of whether the stresses obtained from bakelite or celluloid models can be taken to represent the stress systems in structural materials such as steel, we have both theoretical and experimental evidence to the effect that within certain limitations of little practical interest the stress distribution is independent of the material involved. Thus the mathematical theory of elasticity shows that the continu-

* See H. S. Orr's Master's Thesis in Mechanics, Carnegie Institute of Technology, 1933. See also Thesis by S. Jory, 1935.

ity equation does not involve any elastic constants. Direct measurements of strains and stresses in steel models, such as have been made, further substantiate the photoelastic results.* Photoelestic solutions of problems for which exact or approximate stress functions exist generally show good agreement.†

Figure 8 shows a photograph of a steel disc with a circular hole subjected to diametral compression and subsequently etched by Fry's method. This etching effects the plastic portions of the metal in a different way than the elastic portions of the metal. By comparing such etchings with the corresponding photoelastic stress-patterns, it is possible to obtain a qualitative corroboration of the photoelastic results. Thus, Fig. 8 shows that some of the material

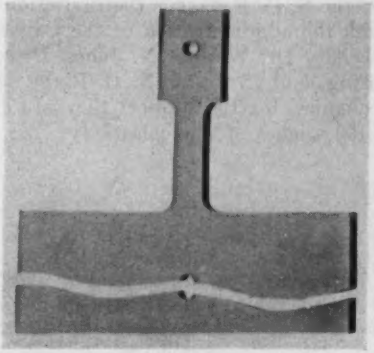


FIG. 9.

surrounding the hole has reached a plastic state, whereas other portions are still elastic. In other words the etching corroborates the formation of stress-concentrations around the hole as predicted by photoelasticity. The etching further shows two elastic islands on the vertical diameter above and below the hole surrounded by a plastic region. This also agrees with the photoelastic stress-pattern which shows fringes of low order at points corresponding to the elastic islands in the steel disc.

To conclude, it is the writer's opinion that photoelasticity is an important and very useful tool for teachers of engineering mechanics and of structural and machine design. It not only calls attention to the present weaknesses in stress analysis, but it provides an

* See work by Y. Sataki reported by Coker in the *General Electric Review*, December, 1920.

† See "Recent Advances in Photo-elasticity," by M. M. Frocht, *Transactions A. S. M. E.*, 1932. Also Filon, Engineering, October, 1923.

effective, constructive means for their elimination. It focusses attention upon and makes possible the determination of stress-concentrations which are probably the most important factor in failures of materials especially in fatigue. The use of photoelasticity as a method of stress analysis in engineering instruction is bound to grow as its merits become widely known and recognized.

Fig. 9 shows a tensile failure of a bakelite model in which the width of the head and of the shank are 6″ and ½″ respectively. The loads were axial through the holes. This photo is from a paper by the author entitled: "Properties of Bakelite and its Behavior at Failure" presented at the annual meeting of the A. S. M. E., Dec. 1935.

The writer takes this opportunity to express his appreciation to the committee of the S. P. E. E. for the invitation to address this body and to thank the administration of the Carnegie Institute of Technology, especially Dr. Webster N. Jones, Director of the College of Engineering, and Professor N. C. Riggs, Head of the Department of Mechanics, for the support they are extending to the development of the science of photoelasticity.

The T-SQUARE PAGE

DEVOTED TO THE INTERESTS OF THE DIVISION OF ENGINEERING DRAWING

FREDERIC G. HIGBEE, EDITOR

College Drafting Rooms: Installation of certain accessories in college drafting rooms may result in marked improvement in establishing high standards of workmanship. Obviously such elements as good light, suitable temperature, and adequate ventilation are essential. Of equal importance is cleanliness: not only must drafting rooms be cleaned and the tables dusted daily but there should be in each room a lavatory with soap and paper towels. About the only way, it has been stated, to keep a drawing room clean is not to get it dirty!

Blackboard space in each drafting room is important; usually blackboards are placed too low for good visibility for sitting draftsmen. Locker space is usually available for the storage of coats and hats but if such space is lacking coat hooks on the wall of the drafting room will at least improve the situation. A clock—and by all means one in step with college time if any—is a convenience of merit. These are all fundamentals which should be a part of the service furnished by the college.

Engineering drawing departments themselves should be responsible for furnishing suitable and *efficiently arranged* drafting tables with stools, and the tables should have provision for safe keeping of equipment. Many small conveniences such as draftsmen's pencil sharpeners, trimming shears, generous-size waste baskets, and a calendar—preferably of the current year—are too often overlooked.

Space for the display of exhibits of student drawing of exceptional quality, and for showing work of professional draftsmen and other informative and interesting matter is worth while, and wall charts of decimal equivalents and other useful and frequently used data are conveniences. And since spring is just around the corner and the fall season for half dead flies is on the way, how about screens for the windows?

Added Pet Peeve! From the official S. P. E. E. "Emblem and Membership Certificate Statement": "PRINT your name . . . exactly as you wish it to appear on the certificate."

CIVIL ENGINEERING DIVISION

FRED L. PLUMMER, *Chairman* — H. C. BIRD, *Secretary*
FRANK KEREKES — K. C. REYNOLDS
L. E. GRINTER — H. E. BABBITT

COMMITTEE ON APPLIED HYDRAULICS

BY F. M. DAWSON

Professor of Hydraulic and Sanitary Engineering,
University of Wisconsin

In considering the duties of the Sub-Committee on Applied Hydraulics of the Civil Engineering Division of the S. P. E. E., the question naturally arises, what can this committee do for the general good of the members dealing with this subject in the colleges of engineering in the United States? The question always arises, "why have a committee?" At first the natural impulse would be that it is not necessary and therefore why bother. However, a little reflection will soon indicate that there are many items which can be better solved by mutual coöperation than by individual work. In some cases this mutual assistance would not involve any particular study or additional work on the part of individuals but only the forwarding of such information as is now available to a central headquarters for compilation and publication.

The committee, of course, might also function along many other lines such as the gathering together of the latest information on research projects, the presentation of abstracts of these projects not only at the annual meeting but furnishing such additional means of making the work known as could be done through the society publications.

Still another function of this committee would be to assist in formulating ideas and providing an opportunity for discussion on the proper methods of teaching. There is a very strong feeling that our main function is instruction and that anything which we as members of the S. P. E. E. can do to help each other along this line should be presented and carried to completion.

With these in mind the Committee on Hydraulics wishes to propose two general topics for discussion during the year and at the annual meeting. Other topics may be added but in the main we would like to accentuate or concentrate on two general features, first, of gathering together pertinent data and information on hydrology and secondly, a rather complete discussion on the use of demonstration lectures in the teaching of elementary hydraulics.

It has been proposed that those who deal with hydrology either as a separate subject or indirectly in the conduct of their work send in to the chairman the following information:

(*a*) The maximum 24-hour rainfall for each year in their own tributary area.

(*b*) An intensity-time curve showing the maximum rates of rainfall which are used for design purposes in storm sewer or culvert design. These curves to apply for the area tributary at each institution. It is realized at once there will be considerable overlapping in these areas, but this overlapping is advantageous rather than otherwise. Attention is called to the excellent publication by Mr. David L. Yarnell, Department of Agriculture, Miscellaneous

Publication No. 204, August, 1933 entitled "Rainfall Intensity-Frequency Data." The charts presented in this bulletin "are based upon the weighted rainfall experience of all weather bureau installations" and includes data up to 1933. It is thought that other sources of information might be available other than the weather bureau stations, such as records of city engineers offices, drainage districts, power companies, irrigation districts, etc. In addition extreme rains may have accrued since 1933. In other words what is proposed is that each institution assemble the data similar to that given in Fig. 20, page 83 of Metcalf and Eddy, "Sewage and Sewage Disposal," or Fig. 15, page 52 "Public Water Supplies," by Turneaure and Russell and send it in to the chairman.

The Committee also is anxious to compile pertinent data which would be useful in teaching courses dealing with the design of storm sewers, soil erosion structures, road culverts, etc. Many engineering colleges have already gathered information on flood flows from small areas in their own immediate locality. Much of this is already available in the literature but frequently it is so scattered and often buried in descriptions of the structures, that it is believed to be a worthwhile project to gather this information together and make it available to each other. Your committee feels it would be of service to the whole profession and particularly to those teaching engineering if it would act as a central agency for the collecting, correlating and publication of such information as is now available but in a scattered and unsatisfactory manner. We believe that this may be done without any hardship or great demand on the time of each one. Collectively we would have something which would be worthwhile.

Insofar as the arrangement for presentation to the annual meeting which is to be held in Madison, your committee is not yet in a position to make a report. It is expected that three general topics will be up for consideration: (1) Hydrology (2) Methods of using demonstration apparatus in the teaching of Elementary Hydraulics and (3) current research in Hydraulics.

EMPLOYMENT SERVICE

The Secretary circularized all engineering colleges asking them to list any vacancies in their staffs. We are receiving these and now ask any member who wishes to change his position to send to this office complete information concerning his education, experience, references, etc. This service is free to members. Information should be sent to the Office of the Secretary, S. P. E. E., University of Pittsburgh, Pittsburgh, Pa.

S. P. E. E. EMBLEM

The emblem comes in two styles, gold and gold-plated, with a blue background and gold lettering. It may be secured in the form of a pin, gold $2.25, gold-plated $1.00; or a charm, gold $3.50, gold-plated $1.25. A member writes: "The S. P. E. E. watch charm emblem came this morning. I want to congratulate you on its appearance. I think it is the nicest thing of its kind that I have ever seen."

The membership certificate is engraved on durable parchment paper, 8½ x 11 inches, suitable for framing—price $2.00. When ordering a certificate, be sure to write your name exactly as you wish it to be engrossed on the certificate.

Orders, accompanied by check, should be sent to the Secretary, F. L. Bishop, University of Pittsburgh, Pittsburgh, Pa.

NEW MEMBERS

BRANCH, WILLIAM H., Educational Sales, Central Station Dept., General Electric Company, Schenectady, N. Y. A. C. Stevens, L. H. Means.

CAMP, CECIL S., Assistant Professor of Civil Engineering, Mississippi State College, State College, Miss. L. L. Patterson, D. M. McCain.

CHESTERMAN, FRANCIS J., Vice President and General Manager, The Bell Telephone Company of Pennsylvania, Pittsburgh, Pa. F. L. Bishop, E. A. Holbrook.

CUNNINGHAM, CHARLES W., Structural Designer, Allegheny County Authority, Pittsburgh, Pa. F. L. Bishop, Nell McKenry.

DOTY, L. DONALD, Assistant Engineer, Chief in charge Order-Budget Section, U. S. Engineers Office, Zanesville, Ohio. Re-instatement.

HEBARD, WILLIAM J., Director of Industrial Relations, Marquette University, Milwaukee, Wis. Stewart Scrimshaw, F. A. Kartak.

LANGDON, HOWARD H., Professor and Head, Department of Mechanical Engineering, State College of Washington, Pullman, Wash. F. W. Welch, E. R. Parker.

LAVALLEY, EDWARD C., Instructor in Engineering Drawing, New York University, New York City. L. V. Carpenter, Heber Dunham.

LINDSAY, JAMES D., Assistant Professor of Chemical Engineering, University of Idaho, Moscow, Ida. L. C. Cady, I. C. Crawford.

LOVELL, C. L., Assistant Professor of Chemical Engineering, Purdue University, Lafayette, Ind. J. L. Bray, A. P. Poorman.

MCGIVERN, JAMES G., Instructor in Mechanical Engineering, State College of Washington, Pullman, Wash. F. W. Welch, H. V. Carpenter.

MOORE, EMMETT B., Instructor in Civil Engineering, State College of Washington, Pullman, Wash. F. W. Welch, M. K. Snyder.

NICHOLS, CLYDE R., Head, Engineering Department, Arkansas Polytechnic College, Russellville, Ark. Siebert Fairman, F. C. Bolton.

NYLAND, WAINO, Instructor in English, University of Colorado, Boulder, Colo. A. S. McMaster, Walter K. Nelson.

RAPPORT, ADOLPH H., Instructor in Electrical Engineering, City College of New York, New Yory City. Harry Baum, G. C. Autenreith.

THORNTON, G. E. Professor of Mechanical Engineering, State College of Washington, Pullman, Wash. F. W. Welch, H. V. Carpenter.

TRAVIS, IRVEN, Instructor in Electrical Engineering, University of Pennsylvania, Philadelphia, Pa. C. D. Fawcett, Harold Pender.

WEIDLEIN, EDWARD R., Director, Mellon Institute, Pittsburgh, Pa. F. L. Bishop, E. A. Holbrook.

WOODBURN, JAMES G., Associate Professor of Hydraulic Engineering, State College of Washington, Pullman, Wash. F. W. Welch, M. K. Snyder.

194 new members July 1, 1935 to March 17, 1936.

AMERICAN ENGINEERING COUNCIL

President A. A. Potter and the Executive Committee have replanned the work of Council committees. Two major considerations have guided such changes where they have been made. In the first place the very large increase in the number of members makes it desirable to organize committees in such a way as to bring about unity of purpose between member organizations. In the second place it has seemed desirable because of the very successful working out of the same procedure for the Public Affairs Committee during the year 1935, to re-group all committees in such a way as to simplify the understanding of the major objectives of American Engineering Council, for the coming year.

To these ends all committees have been grouped under four major headings, the name of each major heading indicating the definite objective of the several committees grouped under it. These four groups and their committees are as follows:

a. Committee on Public Affairs
   1. Aeronautics
   2. Public Works
   3. Government Competition
   4. Conservation and Utilization of Natural Resources
   5. Patents
   6. Rural Electrification
   7. Surveys and Maps

b. Committee on Engineering-Economics
   1. Relation of Consumption, Production and Distribution
   2. Special Surveys and Studies

c. Committee on Programs for United Action of Member Organizations
   1. Publicity—Engineering Profession
   2. Engineers' Economic Status
   3. Merit System in the Public Service
   4. Surveys of Engineers and Engineering

d. American Engineering Council Operating Committees
   1. Finance
   2. Membership and Representation
   3. Constitution, By-Laws and Standing Rules
   4. Publicity—American Engineering Council
   5. Regional Activities

All these committees report to the Executive Committee which functions for the Assembly of delegates from member organizations between the times of the annual meeting.

In addition to the general News Letter, which is mailed to all those active in the work of the Council, arrangements are being made to issue a special News Letter to the members of the General Committee on Public Affairs and to the Public Affairs' representative of the state and local member organizations.

NEW COMMITTEE APPOINTMENTS

J. L. Bray of Purdue University has been added to the Committee on Chemical Engineering.

Committee on Two-Year Terminal Program: B. R. Van Leer, *Chairman,* University of Florida, Gainesville; P. R. Kolbe, R. E. Doherty, B. F. Bailey, J. W. Barker, C. M. Jansky, E. A. Hitchcock, and Louis O'Shaughnessy.

Committee on Summer School in Economics: O. W. Eshbach, *Chairman,* 195 Broadway, New York City; Walter Rautenstrauch, Harvey N. Davis, R. A. Seaton, E. L. Grant, J. W. Roe, D. S. Kimball, H. P. Hammond, P. T. Norton, A. R. Cullimore. (The Summer School in Economics will be held June 28 to July 5, inclusive, at the Stevens Institute of Technology Camp.)

Committee on Summer School for Teachers of Drawing: H. M. McCully, *Chairman,* Carnegie Institute of Technology, Pittsburgh, Pa. (The Summer School for Teachers of Drawing will be held June 19 to 22, inclusive, at the University of Wisconsin.)

COLLEGE NOTES

Massachusetts Institute of Technology.—Vannevar Bush, '16, vice-president of the Institute, and Dean of the School of Engineering, has been awarded the 1935 Lamme Medal of the American Institute of Electrical Engineers for "development of methods and devices for application of mathematical analysis to problems of electrical engineering." Dr. Bush's contribution to the field of electrical engineering was the so-called "thinking machine" which he perfected for the solution of complex mathematical equations. He has won world-wide recognition as the director of the research group which produced the differential analyzer. This machine can perform in a few minutes complicated computations which would require hours for a highly-trained engineer.

To increase the general knowledge of airplane engine performance a research program of some length has been inaugurated under the auspices of the National Advisory Committee for Aeronautics in coöperation with the Automotive Engine Laboratory.

This program includes two problems; the first is the design of a two-cycle engine for aircraft. At present the design of the two-cycle engine presents much greater difficulty than the conventional four-cycle type, largely because the burned gases cannot be forced out of the cylinder by means of the piston but must be displaced by the incoming charge, a process known as "scavengering." The expulsion of the burned gases must be accomplished with a minimum amount of mixing of the burned and unburned charges and with a minimum loss of the fresh charge out of the open exhaust valve. A successfully designed two-cycle engine would have the advantage of obtaining one power impulse per revolution instead of one in two revolutions as in the four-cycle engine. In addition, the ported two-cycle engine is perhaps the simplest prime mover known and is consequently inexpensive to manufacture. It is hoped that the results of this investigation will indicate the possibilities of such a power plant.

The second investigation is that of the dynamic characteristics of the induction system of conventional engines. Because of the inertia of its mass, the air in the inlet pipe of an engine tends to continue its flow after it is once started. Utilizing this inertia, it is possible, without supercharging, to fill the cylinder of an engine with air at several pounds higher than atmospheric pressure and thereby increase the output of the engine. The Automotive Engine Laboratory has been engaged in work along these lines for some

time with a high degree of success. By proper regard for the dynamics of the inlet system it has been found possible to achieve the effects of a moderate degree of supercharging. The results of this work are already having their effect upon modern aircraft engine design, and it is hoped that the completion of this work will make complete data for the design of the induction system available to engine designers.

University of Minnesota.—Professor Jean Piccard, stratosphere ballonist, will be with the Department of Aeronautical Engineering during the spring quarter, 1935–36 from March 28, to June 12th. Elementary and special advanced problems pertaining to stratosphere flying use and construction of equipment will be covered in lecture, laboratory, and seminar courses. Qualified persons interested in a special study of problems relating to the stratosphere, may make arrangements for enrollment as special or regular students in the Department of Aeronautical Engineering or in the Graduate School.

Missouri School of Mines and Metallurgy.—On November 1, 1935, Professor George R. Dean, Professor of Mathematics at the school since 1897, retired on the Carnegie pension.

Professor Dean graduated from the School of Mines and Metallurgy in 1890 in General Science, and in 1891 in civil engineering. He later taught at Maryville Seminary and at Coe College and was for a year student assistant in the Leander McCormick Observatory at the University of Virginia. At his retirement he had completed thirty-eight years of service with the school.

Professor C. R. Forbes, after a three years' leave of absence, has returned to the School of Mines as head of the mining department. In Professor Forbes' absence Professor J. H. Steinmesch served as acting head of the department. Professor Steinmesch is now engaged in special work for the United States Bureau of Mines revising a technical publication dealing with the use of underground loading machines in mines.

Professor J. S. Cullison, Assistant Professor of Geology at the School of Mines, is on a year's leave of absence during the present school year doing special work for the Tennessee Valley Authority. His place on the campus is being filled by Dr. Norman Hinchey.

The enrollment at the School of Mines this year in the freshman class shows a 67 per cent increase over the enrollment in the freshman class for 1934–35. There is also a general increase in enrollment of about 8 per cent over last year.

Yale University.—Beginning with Commencement this June, the degree conferred upon graduating Seniors of the Yale School

of Engineering will be Bachelor of Engineering (B. E.), and the graduate professional degree in engineering will be Master of Engineering (M. Eng.), and the research degree in engineering will be Doctor of Engineering (D. Eng.).

SECTIONS AND BRANCHES

The second annual meeting of the **Illinois-Indiana Section** of the Society will be held Saturday, April 18, 1936, at the Lawson Y. M. C. A., Chicago Avenue and Dearborn Street, Chicago, Illinois. The meeting will be called to order at 10:00 A.M. *Eastern Standard Time.*

The morning session will be devoted to routine business, election of officers, and three addresses of interest to the entire membership. The speakers at this session will be

Professor Hardy Cross, University of Illinois
Dean Townley Heald, Armour Institute
Mr. Lawrence A. Downs, President, Illinois Central System

Lunch will be served in the Y. M. C. A. cafeteria.

The afternoon session will be devoted to the following group conferences:

Physics—Professor J. S. Thompson, Armour Institute, Chairman. This conference will be a joint meeting of our group with the Chicago Section of the American Association of Physics Teachers.

Mathematics—Professor C. E. Paul, Armour Institute, Chairman.

Electrical Engineering—Professor A. R. Knight, University of Illinois, Chairman.

English—Professor Walter E. Hendricks, Armour Institute, Chairman.

Fluid Mechanics—Professor W. E. Howland, Purdue University, Chairman.

Mechanical Drawing—Professor R. P. Hoelscher, University of Illinois, Chairman.

Chemical Engineering—Professor C. L. Lovell, Purdue University, Chairman.

Entertainment for the Ladies

Mrs. Willard E. Hotchkiss, President of the Armour Faculty Woman's Club, is Chairman of the Committee arranging for entertainment of ladies attending. Headquarters for the ladies will be at The Chicago Woman's Club, 72 East Eleventh Street. Luncheon will be served at 75 cents per person. The hospitality of the club will be extended. Armour women will assist in planning morning

or afternoon trips to the stores, museums or elsewhere. Women or men guests who wish to remain at the club over night will be provided for at $2.00 each.

It is requested that those planning to attend notify Mr. Charles O. Harris, Armour Institute of Technology, Chicago, Illinois, Chairman of the Armour Committee on Arrangements, and advise whether they will be accompanied by ladies.

The Spring meeting of the **Middle Atlantic Section** of the S. P. E. E. will be held at Union College, Schenectady, N. Y., May 15 and 16, 1936. This meeting is being sponsored jointly by Rensselaer Polytechnic Institute, General Electric Company, and Union College. An invitation is extended to those living in vicinity of the meeting place. The tentative program is:

Friday, May 15

9:30. Registration at General Electric Company.
10:00. Inspection trip at General Electric Company.
12:45. Complimentary luncheon at General Electric Company.
1:30. Parallel inspection trips and conferences as follow:

Conference on Electrical Engineering.
Conference on Mechanical Engineering and Machine Design.
Conference on Chemical and Metallurgical Engineering.
Conference on Civil Engineering.
Inspection trip to Carpet Mills, Amsterdam.
Inspection trip to U. S. Arsenal, Watervliet.
Inspection trip to American Locomotive Co., Schenectady.
(If there is a demand, special inspection trips can be arranged to W. and L. E. Gurley Co. at Troy; Schenectady Sewerage Plant; special trips in the General Electric Co. Plant; or other trips of interest in the vicinity.)

4:00 to 5:30. In Rice Hall at General Electric Company. Program to include talks by Dr. W. R. Whitney and Dr. W. D. Coolidge and a demonstration of the late developments in the Research Laboratory.
6:30. Dinner (Place to be arranged). Greetings from Dixon Ryan Fox of Union College, W. O. Hotchkiss of Rensselaer Polytechnic Institute, and F. L. Bishop, Secretary of the Society. Address by Dr. Irving Langmuir.

Saturday, May 16

9:00. Registration at Union College.

9:30. Professional Session, Old Chapel. Chairman, Professor Frank L. Eidmann.

1. Training the Engineer to Sell His Services.
   (*a*) Trend of future openings. C. C. Williams, President, Lehigh University.
   (*b*) Where are our best men of past years now employed? M. M. Boring, General Electric Company.
   (*c*) How can we train the undergraduate to sell his services? Howard L. Davis, N. Y. Telephone Company.
2. Progress Report on Accrediting Engineering Schools. Speaker to be suggested by E. C. P. D. Committee on Engineering Schools.
3. Recent Trends in Engineering Education. C. F. Scott, Yale University.

12:00. Luncheon in Alumni Garden. Address by Dean Dexter S. Kimball, Cornell University.

2:00. Inspection of laboratories, Union College.

3:00. Inspection of laboratories, Rensselaer Polytechnic Institute.

The officers of the **Texas Section** for 1935–36 are as follows: *President,* O. V. Adams, Texas Technological College; *Vice President and Chairman of the Program Committee,* C. W. Crawford, A. and M. College of Texas; *Secretary-Treasurer,* J. A. Orr, A. and M. College of Texas; *Executive Committee* (3 year term ending 1938): L. V. Uhrig, Rice Institute, C. E. Rowe, University of Texas, N. F. Rode, A. and M. College of Texas.

REPORT OF CONFERENCE ON ENGLISH, GEORGIA SCHOOL OF TECHNOLOGY, ATLANTA, JUNE 24 AND 25, 1935

Three sessions made up the Conference on English at the Atlanta meeting. Two topics were given special attention:

Extent and Kind of Literature Courses in an Expanding Engineering Curriculum.

Writing Demands in the Four-Year Engineering Curriculum, and the Responsibility of the English Department.

Though the group of English teachers was small, it was alert, vigorous and looking forward toward the service that teachers of English in technical schools can render, and the contribution they can make toward the training of the well-rounded engineer.

This service is through the formal English composition courses that have to do with basic principles for the writing of expository discussion—largely the report. The feeling of the group seemed to be that these composition courses should have as their aim the development of skill in effective presentation in the types that will be required in succeeding college courses. Not only the forms peculiar to expository writing should have attention but also the mechanics of writing—grammar, spelling, sentences and paragraphs, usage and vocabulary—should be sufficiently stressed for students to maintain acceptable standards in all their college writing. In fact, the stress put upon the necessity for training in the elementary principles such as those just enumerated seemed almost disproportionate. There was some tendency to lose sight of the irrefutable fact that after all accuracy in the mechanics of writing is not an end in itself but a means to an end—the effective, vivid, accurate communication of ideas. No final conclusion, however, has yet been reached as to whether drill on the mechanics of writing, at the expense of practice in coherent writing in the few composition courses offered engineering students brings any more lasting results than the stimulation to interesting ideas that challenge the student to express himself accurately so that the mechanics of writing will not interfere with the vivid presentation of his thoughts.

The contribution of English to the education of the technical student is through literature, that is, the reading of great books of all ages. By this means, the technical student may be made aware

of the world about him, its social trends, the significance of breadth of view, and the desirability of discovering new dimensions to all aspects of his training, as well as to his individual contribution to the progress of his generation. When the engineering curriculum has expanded sufficiently to admit more English, it is safe to say that English teachers to technical students will be prepared to offer those courses in literature that will meet more adequately than is now possible, the cultural needs of the engineer in a new order. There was discussion of the means that were used in the different schools represented to get students to read extensively in connection with the literature courses. Reserve shelves, ten minute daily quizzes, a definite daily assignment, parallel reading and the reading aloud of portions of books assigned by the instructor as a part of the class hour were some of the methods employed.

Two projects of Engineers' Council for Professional Development were brought to the attention of the group:

General Robert I. Rees, chairman of the committee on Professional Training, discussed the reading lists for junior engineers, based upon recommendations by a number of eminent engineers. This list is presented for the young engineer "who is desirous of broadening himself and developing a full professional life." Of special interest to English teachers, of course, are the books included under *literature, including poetry, essays, and fiction, biography and travel.*

The second project of E. C. P. D. brought to the attention of the group was the study of pre-engineering students by the Committee on Student Selection and Guidance with Dean R. L. Sackett, Chairman. The purpose of this project has been to find a test that would predict scholastic success in an engineering curriculum by a testing program given a prospective student of engineering before he enters this curriculum. As an initial program, Coöperative English test, series 1, form 1934 and Coöperative General Mathematics test for college classes, form 1934 were given early in September, 1934 to freshmen students enrolled in the several curricula of nine colleges of engineering. The scores made in the tests were to be compared and correlated with the average grades made by the individual students at the end of the first, second, third and fourth years. Of course, as these tests were given first in 1934 and the plan is to have them cover at least four years, the analysis of the first year results can only be general. At the time of the English Conference all the data from the participating schools had not been analyzed. Of most significance to English teachers were some comments of Professor C. E. Bullinger, Pennsylvania State College, who analyzed the results of the test there: "The English usage part of the total English test," said Professor

Bullinger, "is better than any other and is better than the whole. . . . It has been suggested that both the English course and the English test deal with something which is not used very much in engineering subjects. In other words, the English courses deal with composition which is apparently little used in engineering classes, at least as a basis for grades. It is possible that an English test devised to measure comprehension of reading would show better results. Perhaps more stress should be put upon reading for comprehension by courses in English and by instructors in engineering. It may be that through the development of the ability to comprehend what one reads, the student may be able to express himself through the written word."

The round table discussion of problems of immediate interest to English teachers, under the leadership of C. W. Park, University of Cincinnati, brought the value of the personal conference, a teaching method which was thought indispensable; the best means of teaching the mechanics of writing; the grading of papers. The desire was expressed that there be a clearing house committee on English to carry on the work of the Atlanta conference. The interchange of exercises that have been successful in teaching English and hints on work not adequately covered by textbooks was particularly recommended. A motion was passed that a plan be formulated by which exercises not available in textbooks be sent to the Chairman of the Committee on English to be mimeographed and mailed out to interested teachers of English. Plans were also made at the English conference that teachers of English in different institutions with similar interests should keep in touch with one another throughout the year, work on some particular project of mutual interest and report their project and their conclusions at the Conference on English at the Annual Meeting in 1936.

Comments by English teachers attending the Conference on English for the first time seemed to indicate that they have been impressed with the feeling that the Society is not only interested in the English in the engineering curriculum, but that it is back of English to such an extent that membership in the Society is extremely beneficial to English teachers. This impression arose from the interest in and the attendance at the session of those whose major interests are the technical and administrative features of engineering education.

SADA A. HARBARGER,
Chairman

BOOK REVIEWS

Alternating Current Machines. ALBERT F. PUCHSTEIN AND TOM C. LLOYD. New York, Wiley Book Co. 582 pages. $5.00.

The book is divided into ten parts with from two to eleven chapters devoted to each. A total of 115 problems referring to thirty-eight chapters are included at the close of the book.

The book is unique with its "only one of its kind" arrangement of material and also the uniform system of treating each subject in the following order: (1) Construction, (2) Operating Characteristics, (3) Calculation of Operating Characteristics from Tests, and (4) Analyses of Various Related Phenomena.

A very extensive bibliography has been appropriately and very wisely included which will make the study more interesting and helpful to the student who reads the book.

In conclusion I think that by and large the authors have made a real contribution to the literature on Alternating Current Machinery. It will be a good guide for such a course in any Electrical Engineering Department.

R. C. GORHAM

Fundamentals of Industrial Marketing. ROBERT F. ELDER. New York, McGraw-Hill Book Company, Inc., 1935. viii + 317 pages. $3.

Professor Elder of M. I. T. offers a valuable contribution to the management field, both from a practical and an academic viewpoint. The author has drawn together the experience of concerns engaged in industrial marketing and has related this experience to the fundamental principles of marketing.

That the book "relates actual practice and industrial marketing *to economic principles*" is a misstatement on the jacket of the volume which is nowhere claimed by the author.

Since most industrial plants are characterized by decreasing costs with increased production, the lowering of the selling price is an important factor in competition and influences consumer purchases. This feature of price reductions, rising out of the desire for economy in production, has been developed on a practical and a theoretical economic basis.

This book is a careful, well written contribution to the industrial marketing field. Not only is the book suitable as a text in engi-

neering schools giving this subject, but it is an excellent reference for undergraduates, graduates, teachers and engineers concerned with management in its broader aspects. Certainly this subject is receiving more attention both from industrialists and educators, because it is one thing to manufacture a product and quite another thing to sell it. Professor Elder's book is a timely addition to management and marketing literature.

E. DILLON SMITH

G-E *Campus News*

X-RAY FOR ART'S SAKE

S there a portrait of Great Uncle Ezra gathering dust in the attic? It may pay to ay Uncle before handing him over to the kman, for behind Ezra's imposing whiskers y be hiding the sister of the Mona Lisa.

t long ago, a portable G-E X-Ray Corration unit disclosed a valuable canvas by e seventeenth-century artist, Goya, conled under an apparently worthless picture. re recently a New Orleans painter and art ert has used the x-ray to discover a genuine Vinci signature beneath layers of paint led by a later and less-capable artist. A w painting to the newly found da Vinci ntly sold for a quarter of a million dollars.

e x-ray does more than discover lost Old sters; it tells how the great artists of the worked. A series of radiographs can dise the full story of their brushwork from first sketch to the last correction. The student of today, by an intelligent use of x-ray, is in a position to take lessons from geniuses of the past.

RE BRIGHT SPOTS ON THE GLOBE

HE mellow, golden-orange glow of sodium ighting is springing up all across the conat. The latest installation, the largest in United States, is located in the state of shington. Here sixty-six 10,000-lumen Gen Electric units line almost three miles of four-lane Pacific highway between Tacoma Fort Lewis.

Less than three years ago the sodium lamp made its first American appearance on a highway near Schenectady. Today the largest installation is on the Pacific coast, and the second-largest is at Lynn, Mass., on the Atlantic. In between, highways, bridges, traffic circles, and underpasses are being lighted for safety with these new luminaires, and G-E sodium lighting units have been installed in Canada, Hawaii, India, Spain, South Africa, Dutch East Indies, and Brazil.

NO CLICK!

THE life of the party, coming home with the milkman, need no longer fear the betraying click of the light switch if his house wiring includes the latest electric switch developed in the G-E Research Laboratory.

Two shallow chrome-steel cups, sealed together with a strip of glass, form the two contacts. A ceramic disk with a hole in it, and a few drops of mercury, partly fill the enclosure between the cups. The device is filled with hydrogen and sealed by welding. In the "off" position, the hole in the disk is above the mercury level. A rotation of twenty degrees to the "on" position permits the mercury to flow through the hole and make the electric connection.

The time-honored click of the switch is abolished. In the laboratory in Schenectady, one of these mercury switches has turned a 200-watt lamp on and off some 65 million times in the last two years, and there are no signs of wearing out or failure.

96-245FBI

GENERAL ELECTRIC

TENSILE & BEND TESTING MACHINE FOR WELDED COUPONS

ACCURATE
SELF-CONTAINED

Simplicity in Construction

• • •

Easily Transported

Tools For Tension & Bend Tests Furnished with the Machine

40,000 LBS. CAPACITY

For FIELD, SHOP and LABORATORY USE

Extremely Accurate Gage Is Hand Marked And Has Maximum Load Pointer

TINIUS OLSEN TESTING MACHINE COMPANY

504 NO. 12th ST., PHILADELPHIA, PENNA.

11 NEW McGRAW-HILL BOOKS

***Davis*—ELEMENTARY PLANE SURVEYING. Text and Manual**

By Raymond E. Davis, University of California. 415 pages, $3.00

***van Wert*—AN INTRODUCTION TO PHYSICAL METALLURGY**

By Leland Russell van Wert, Harvard University. 272 pages, $3.00

***Terry and Wahlin*—ADVANCED LABORATORY PRACTICE IN ELECTRICITY AND MAGNETISM.** *New third edition*

By the late Earle Melvin Terry; revised by Hugo Bernard Wahlin, University of Wisconsin. 322 pages, $3.00

***Nelson*—PETROLEUM REFINERY ENGINEERING**

By W. L. Nelson, University of Tulsa. *Chemical Engineering Series.* 647 pages, $6.00

***Staley*—MINE PLANT DESIGN**

By W. W. Staley, University of Idaho. 383 pages, $5.00

***Young and Young*—ELEMENTARY ENGINEERING THERMODYNAMICS**

By Vincent W. Young, Oklahoma A. & M. College, and Gilbert A. Young, Purdue University. 220 pages, $2.50

***Harding and Canfield*—LEGAL AND ETHICAL PHASES OF ENGINEERING**

By C. Francis Harding and Donald T. Canfield, Purdue University. 420 pages, $4.00

***Smith*—PRACTICAL DESCRIPTIVE GEOMETRY.** *New fourth edition*

By William Griswold Smith, Northwestern University. 283 pages, $2.50

***Hickerson*—HIGHWAY SURVEYING AND PLANNING.** New second edition of the author's *Highway Curves and Earthwork*

By Thomas F. Hickerson, University of North Carolina. 424 pages, $3.50

***Bauer*—PLAIN CONCRETE.** *New second edition*

By Edward E. Bauer, University of Illinois. 364 pages, $4.00

***Moore*—TEXTBOOK OF THE MATERIALS OF ENGINEERING.** *New fifth edition*

By Herbert F. Moore, University of Illinois. 418 pages, $4.00

Send for copies on approval

McGRAW-HILL BOOK COMPANY, Inc.

330 West 42nd Street **New York, N. Y.**

A Complete Plant Under One Roof

PRINTING ~ BINDING ~ ELECTROTYPING

PRINTERS OF

SCIENTIFIC AND TECHNICAL JOURNALS AND BOOKS

THESES AND DISSERTATIONS

WORKS IN FOREIGN LANGUAGES

Your Book, Journal or Thesis placed with us insures that the composition, proof-reading, electrotyping, presswork and binding, follow through in consecutive order in one plant —established fifty-nine years ago—and under the supervision of one management.

LANCASTER PRESS, INC.

LANCASTER, PENNA.

Established 1877

[*Printers of The Journal of Engineering Education*]

I. C. S. INSTRUCTION TEXTS

The following titles are chosen from the list of about 500 small bound volumes of International Correspondence Schools' texts, because of the fact that they have been the leaders in the sale to colleges during the fall semester. Several of these volumes have sold in total quantity of more than 250 copies each since August.

Title	Price
High Speed Diesel Engines	$1.80
Diesel Engines, Details and Management	2.00
Stationary Diesel Engines	1.75
Air Conditioning, I	1.65
Air Conditioning, II	2.00
Application of Refrigeration	1.25
Electric Illumination	1.50
Interior and Exterior Lighting	1.75
Science and Art of Illumination	1.30
Geometrical Drawing	1.50
Elementary Perspective Drawing	1.50
Practical Projection	2.50
Reinforced Concrete Design	1.75
Earthwork and Retaining Walls	1.75
Foundations	1.40
Mapping and City Surveying	2.00
Municipal Sanitation	1.75
Sewerage	1.50
Water Supply	1.75
Building Superintendence	3.50
Methods of Mining Coal, I	1.25
Methods of Mining Coal, II	1.25

Send for catalog and on-approval copies for examination

INTERNATIONAL TEXTBOOK COMPANY

SCRANTON, PENNSYLVANIA